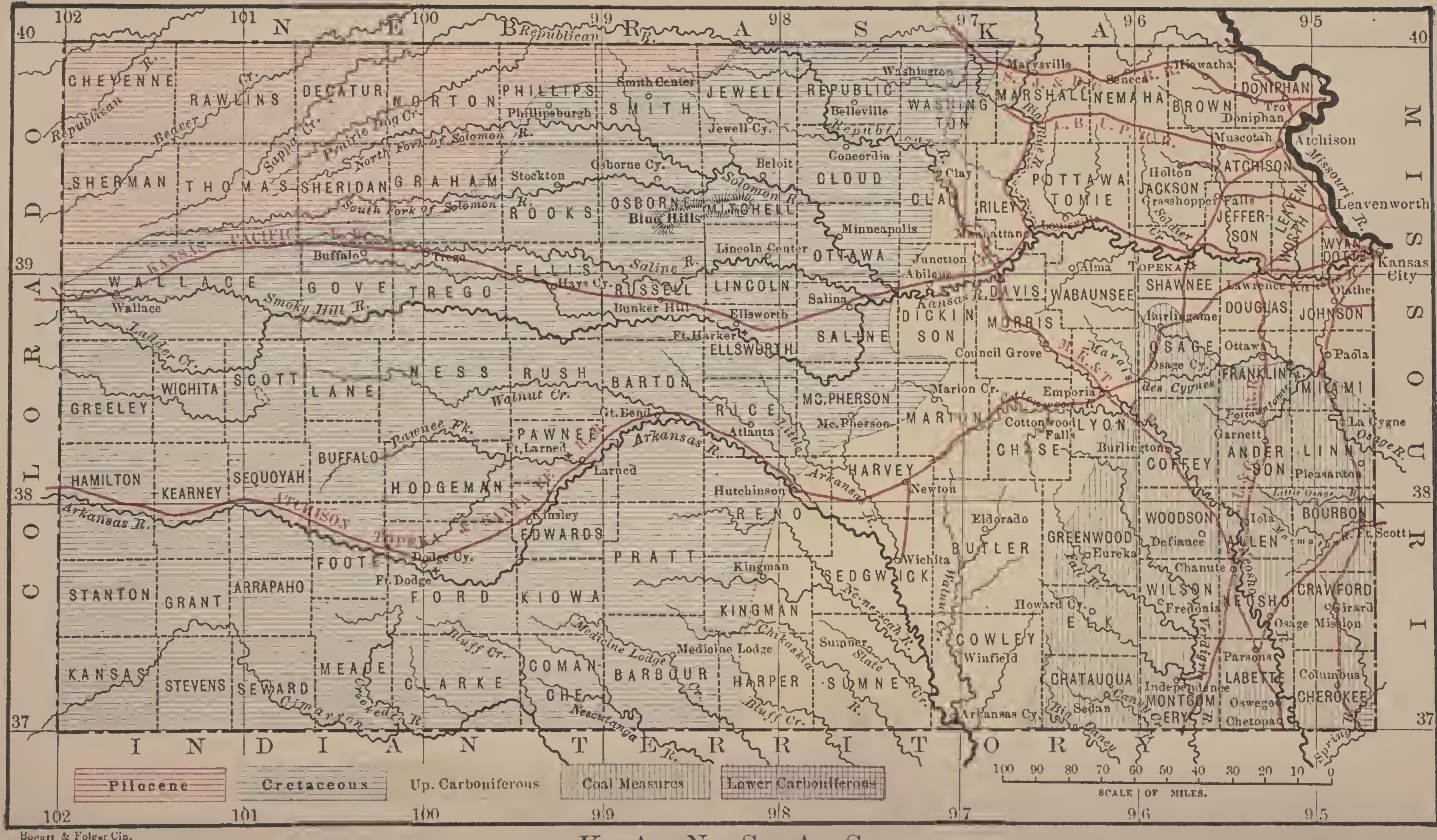
Agricultural Geology

Kedzie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Pliocene
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RILEY
POTTAWATOMIE
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ATCHISON
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CHEROKEE
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Kansas City
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KANSAS.

THE

ELEMENTS

OF

AGRICULTURAL GEOLOGY

FOR THE SCHOOLS OF KANSAS

BY

WM. K. KEDZIE, M.S.

Of the Kansas State Agricultural College

WILSON, HINKLE & CO.

137 WALNUT STREET
CINCINNATI

28 BOND STREET
NEW YORK

[1877]

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PREFACE.

The preparation of this little work, has been undertaken at the very urgent solicitation of the State Superintendent of Public Instruction, and at that of other prominent educational workers. Two objects have been held in view:

First: To place in the hands of teachers a book which would enable them to meet the requirements for the "A" certificate, as given in Article VI, Section 6, of the Session-laws of 1876, which requires, among other things, that the applicant shall be familiar with "the elements of geology, so far as relates to the manner of formation of soils and their adaptation to purposes of production."

Second: To arrange the work for use in the instruction of the more advanced pupils of the common schools.

To the latter end, it has seemed best to keep the book entirely simple and untechnical in its character and language. Common names are therefore preferred to technical terms, and the latter, as a rule, are only used parenthetically. The wants of *Kansas* teachers and students have been regarded above all else; and special attention

has been given to the geology, mineral resources, and farm soils of this State.

At the outset of the work, the author was, very naturally, embarrassed by the fact that, although knowing of no book having similar objects in view, much of the work had already been notably performed, in different fields, by Professors J. D. Dana and S. W. Johnson. The author, therefore, addressed these gentlemen, stating the case, and received from them full permission to make such use of their writings as might be found necessary to the ends in view. It will only be necessary, then, to state explicitly that most of the elementary geology, in Part First, is based upon Professor Dana's "Manual of Geology;" and that much of the origin and classification of soils, in Part Second, is founded on the chapter on soils, in Professor Johnson's "How Crops Feed."

The author desires also to express his obligations to Professor B. F. Mudge, Judge F. G. Adams, General John Fraser; and, above all, to Professor Orestes St. John, for many kind suggestions; also, to Hon. Alfred Gray, for use of the geological map of the State.

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NOTICE TO TEACHERS.

WHEREVER possible, teachers should construct a map of the school-district or township in which the study is being pursued, with a careful designation and description of the rock strata. A collection of these rocks, and of the soils adjoining them, should be made also, as it will frequently prove of much assistance in pointing out the relations which exist between soils and the rocks from which they have been derived.

As will be seen, this book has been written on the supposition that an abundance of specimens, both of soils and of the minerals composing them, will be placed in the hands of the pupils studying it. Such specimens are very important, both for a perfect understanding of the subject, and for the interest which they excite.

Many specimens of soils, and a small portion of the minerals, can be obtained in almost any locality in Kansas. It may not always be possible, however, to obtain a satis-

factory collection; and, wherever it is desired, the author will be glad to lend his assistance, and will furnish a *complete set* of the soils and minerals described in the book, charging only for the actual cost of collection. Any communications may be sent to his address as given below.

Wm. K. Kedzie,
State Agricultural College,
Manhattan, Kansas.

PART FIRST.

ELEMENTARY GEOLOGY.

ELEMENTARY GEOLOGY.

SECTION I.

FORMATION OF THE EARTH'S CRUST.

1. **Definition.**—Geology is that science which treats of the structure of the earth; of its history, of the composition of its rocks, and of the causes which have formed them and placed them in position.

2. **The Earth.**—The earth on which we live is, in shape, a globe or sphere, about 25,000 miles in circumference, and slightly flattened at its poles. The average diameter of the earth is about 8000 miles; its diameter from one pole to another being about 26½ miles less than its diameter through the equator. Hence, we know it to be slightly flattened.

3. **The Earth once a molten mass.**—Geology teaches us that countless ages ago the whole earth was a mass of melted matter; that from the intense heat which then prevailed, all rocks and all solid matter were in a liquid condition. The earth must then have reached its present state through a process of cooling; a crust of solid rock, slowly increasing in thickness, would thus be formed over its entire surface. Much of the earth's interior is even now supposed to be in a molten condition, because over many portions of the globe large quantities of melted rock are frequently thrown out from volcanoes. It is not

generally believed that the whole of the earth's interior is in a liquid state, but that there are large internal seas of melted matter, each finding its escape through one or more volcanic openings.

4. **Contraction of the Earth's crust.**—As this cooling process continued, the exterior crust of solid rock would gradually increase in thickness. But we know that nearly all bodies, in the process of cooling from a high temperature, shrink or contract powerfully, and tend to grow smaller in bulk. Hence, the first rock crust of the earth would not long remain smooth and even upon its surface, but by the force of contraction would become folded, wrinkled, and uneven in appearance. Portions would become pressed up into great folds, by which high hills and mountain ranges would be formed; other portions would be depressed by the same force much below their first level, and would thus produce valleys and ocean beds. Between these two extremes we would find every variety of low-lands and high table-lands.

5. **Changes slight compared with the Earth's mass.**—While these elevations and depressions of the earth's crust appear very great to our eyes, they are really very insignificant when compared with the entire mass of the earth itself. It is about 4000 miles from the circumference to the center of the earth; but the deepest ocean sounding is only about 50,000 feet below water level, and the highest mountain peak (Everest) but 30,000 feet above it. The *mass* of mountain ranges is also comparatively small; the entire range of the Pyrenees, spread over Europe, would raise the surface but six feet. Thus we see that the mountain ranges and ocean beds upon the earth's surface are really much less in proportion than the folds and wrinkles upon the surface of an orange.

6. Formation of Rock Layers.—These changes of level which are here described must have taken place very gradually, extending many thousands of years through the earth's geological history. As soon as the surface crust became sufficiently cooled, the dense clouds of vapor of water, which had surrounded the earth like a mantle, would be deposited upon its surface. Hence, we suppose that nearly, if not the whole surface of the earth was at one time covered by a shallow ocean. By the constant wearing action of the waves of this great ocean, the underlying rock crust would be worn away, deposits of fine material—small pebbles, sand, clay, etc.—would be formed, and thus would begin the formation of the first or lowest rock layer or bed. Upon this first "stratum," followed the formation of the later rock layers in succession through each period of the earth's history, and thus has been made the "basement of rock beds," which every-where underlies the soil and waters of the earth's surface. Other beds appear to have been formed by the waters of rivers and lakes. Many show the marks of ripples and waves made while the rock material was still in the state of a fine powder. Some, after having become solidified, were cracked by strong upheavals, and the openings were filled with melted rock forced up from below. The rock layers of the same period differ upon different portions of the earth's surface, and are not all found at any one place. Every indication shows that they must have been formed with extreme slowness, accompanied and followed by many upheavals and depressions of the earth's crust, and frequently much altered by the action of heat. "These different beds vary from a few feet to hundreds of yards in thickness. The different kinds are spread out over one another in many alterations. Sometimes they are

in horizontal layers; but very often they are inclined as if they had been pushed or thrown out of their original position; and in some regions they are crystallized. By careful study of the rocks of different countries, it has been found that the series of beds, if all were in one pile, would have a thickness of 15 or 18 miles. The actual thickness in most countries is far less than this."—*Dana*.

7. **Interior Rock Crust.**—While these rock layers have been forming above, the original crust of the earth itself must have been steadily cooling and increasing from within. But we know almost nothing of this interior rock, as it is beyond our reach and observation.

By careful examination of the rock layers within our reach, we are able to describe accurately the changes through which the earth has passed from the earliest period to the present time.

SECTION II.

I. MINERAL ELEMENTS OF THE ROCKS.

8. Rocks.—"By the word *Rock* in Geology is meant any formation of rock material, whether solid or otherwise."—*Dana.* *Example.* Sandstone is a rock; clay slate is a rock. But as all sandstones were first composed of loose grains of simple sand, and all slates, of more or less pure clay—and these are found in all grades of solidity and hardness,—we can not draw an absolute line, but apply the word rock to any naturally formed bed, whether of solid or of loose earthy material. All rocks are composed of one or more minerals.

9. **A Mineral** is a natural substance, generally composed of two or more elements, which has a uniform structure, and which has not been organized by life.—*Ex.* Quartz and marble are both minerals. There are now known about 600 species of minerals.

10. **An Element** is any *simple* substance.—*Ex.* Iron, charcoal, and sulphur are elements.

11. **A Crystal** is the natural form of a mineral. A rock is said to have a crystalline or crystallized structure when the minerals composing it are found in the form of crystals. Each mineral has its own peculiar crystalline forms which it always assumes.

We shall now consider some of the most important minerals which go to make up the mass of rocks.

12. **Quartz.**—Quartz, also sometimes called *Silica*, is the most abundant mineral known, probably constituting, with its compounds, nearly one-half the earth's crust. When pure, it appears like glass, and is found in crystal prisms, which have six sides and end in six-sided pyramids. It is very hard, scratching glass easily, and can not be melted. Its more impure forms are frequently yellow, brown, or black in color. Flint, jasper, and agate are varieties of quartz. Sand is also nearly pure quartz, as is much of the gravel and pebbles which are washed out by streams.

13. **Silica with other Minerals.**—A very large and important class of minerals consists of compounds of silica with other mineral substances. These compounds are called *Silicates*. The following are the most important substances which form these compounds:

14. **Aluminum.**—This is a beautiful bluish white metal; very light, being about as heavy as glass. It is as strong as iron, and is remarkably sonorous—that is, when struck it rings like a bell. It is only used for jewelry and fine instruments, and is very interesting, because, when united with the oxygen of the air, it forms:

15. **Alumina**;—a white, hard, infusible substance, which is the basis of all clays and clay rocks. *Emery powder* is a good example of nearly pure alumina.

16. **Magnesia.**—This is most familiar to us in the form of *calcined magnesia*. It is white, infusible, and insoluble.

17. **Lime.**—This we all know as ordinary *quick-lime*.

18. **Potash and Soda.**—These are the common alkalies.

19. **Oxide of Iron.**—This is most familiar to us in its

common form of *iron rust.* It forms part of many minerals, and causes the yellow and red color of many soils. Sometimes all of these substances, and sometimes only two or three of them, are combined together to make the minerals called *Silicates.* We shall consider some of the most important.

20. **Feldspar.**—This mineral is composed of silica, alumina, and potash. A variety called *Albite* contains soda instead of potash. It is a white mineral, sometimes having a tinge of red, and splits easily and smoothly in two directions. When converted into powder by the action of the weather, it forms the principal bulk of all clays.

21. **Kaolinite.**—This is pure clay, and is produced from feldspar by the wearing action of water, frost, etc. It is generally found in the form of a fine, soft, yellowish white powder. The various kinds of clay—such as pipe clay, brick clay, blue clay, etc.—consist of kaolinite mixed with more or less other impurities.

22. **Mica.**—This is the mineral commonly, but wrongly, called *Isinglass.* It is a compound of silica, alumina, potash, lime, magnesia, and oxide of iron. It splits very easily into thin, tough leaves, as transparent as glass, which are often used in stove doors.

23. **Pyroxene and Hornblende.**—Both these minerals are compounds principally of silica, magnesia, lime, and oxide of iron. They are generally black or greenish black in color, although some fine varieties are white. The beautiful fibrous mineral called *Asbestos* is a variety of hornblende.

24. **Talc or Soapstone.**—This is a compound of silica, magnesia, and water. The finer varieties, found in thin scales or plates, are called *Talc;* the coarser varieties, *Soapstone.* The mineral is of a gray or greenish gray color.

and remarkable for its greasy or soapy feeling,—whence its name.

25. **Serpentine** is a mineral having the same composition as talc, but harder, finer grained, and of a rich dark green color.

26. **Carbon.**—Carbon is an element which is familiar to us in three forms: First,—the diamond, the hardest substance known; second,—plumbago, commonly called black lead; third,—charcoal. All varieties of mineral coal consist of nearly pure carbon.

27. **Carbonic Acid.**—When carbon in any form is burned, it unites with the oxygen of the air and becomes a gas called *Carbonic Acid* (properly carbonic anhydride). This gas exists in small quantities in the atmosphere—about 4 to 6 parts in 10,000. It is produced not only in the burning of wood and coal, but is thrown out of the lungs of animals in the process of breathing.

28. **Carbonates.**—Carbonic acid gas, in the presence of water, unites with a large number of other mineral substances, and produces a very important class of minerals called *Carbonates.* The following are the more common:

29. **Calcite.**—The simplest form of this mineral in Kansas is seen in ordinary limestone. Marble is the same mineral in its crystalline form. Chalk is still another variety. In all of its forms, this mineral is a compound of carbonic acid and lime. When crystallized it splits easily in three directions. When any acid (such as vinegar) is poured upon it, it dissolves rapidly with violent bubbling from the escape of the carbonic acid gas, which passes off again into the air. This mineral forms a very large and important part of the rock layers of the earth.

30. **Dolomite** is a compound of carbonic acid, lime, and magnesia. When found in massive beds, it forms

magnesian limestone, which may be distinguished from common limestone by its dissolving much more slowly in acids. It is a common and important mineral.

31. **Gypsum.**—This mineral is a compound of sulphuric acid, lime, and water. It is found in large beds in Kansas. When pure it is called *Selenite*, and is colorless and transparent. It is frequently found in compound crystals shaped like arrow-heads. The less pure varieties are of a gray or flesh-red color. It is from this mineral that *plaster of Paris* is made.

II. CLASSIFICATION OF THE ROCKS.

32. For convenience in the study of the rocks, we can easily divide them into classes. We may do this by two methods: 1st. By their origin; 2d. By their structure. By their *origin*, we should form three classes of rocks: (1) Igneous Rocks; (2) Sedimentary Rocks; (3) Metamorphic Rocks.

33. **Igneous Rocks** are those which have been thrown out in a melted state, from which they have cooled to their present condition. *Ex.*—Lava from volcanoes.

34. **Sedimentary Rocks**, as the name signifies, are those which have been formed by the deposit of loose fragments, or sediment, such as mud, sand, gravel, etc., which have afterward become cemented together into solid rock. *Ex.*—Our common limestones are sedimentary rocks. Rocks of this class have generally been deposited under water.

35. **Metamorphic Rocks** are those which have been formed by the deposit of fine particles, or sediment, and afterward much altered (metamorphosed) by the action of

heat. Where there was only a moderate degree of heat, the rock was simply baked into a solid mass; but where the heat was very intense, it became crystallized. *Ex.*—White marble is a metamorphic rock, produced by the action of heat on ordinary limestone. From their *structure*, we may divide rocks into two classes: 1st. Crystalline Rocks; 2d. Fragmental Rocks.

36. **Crystalline Rocks** are those in which the material of which the rock consists has a crystalline structure. In the coarse-grained rocks of this class, the crystals are easily seen with the naked eye; but in the finer grained varieties they are invisible. Crystalline rocks, again, may be divided into two classes: 1st. Siliceous, or Quartz, Rocks; 2d. Calcareous, or Lime, Rocks. Among the more common varieties of the first class are:

37. **Granite.**—This is a compound rock consisting of quartz, feldspar, and mica. It is either light or dark gray, or flesh red, according to which of the three ingredients is present in greatest quantity. It is found in all grades, fine and coarse grained.

38. **Mica Slate** differs from granite in containing a much larger quantity of mica. This rock is arranged in parallel layers, and splits easily into thin slabs of a glistening gray color. It is frequently used for whetstones.

39. **Clay Slate.**—This is a very fine-grained rock, and but slightly crystalline in structure. It is found in many colors—black, green, red, and gray. It splits very easily into smooth, hard sheets, which are used for roofing material and for writing-slates.

40. **Talcose Granite** differs from ordinary granite in containing talc instead of *mica*. It is grayish or greenish in color, and has a greasy feeling.

41. **Talcose Slate** contains still more talc, and hence

is more smooth and greasy in its feeling. It readily splits into grayish-green plates.

Of the igneous rocks, there are two of special interest:

42. **Trap**;—a fine-grained, dark brown or black rock, of ancient igneous origin. The Palisades of the Hudson River are good examples of trap rock.

43. **Lava.**—The word lava is applied to any rock which has been thrown in a melted state from a volcano. Modern lavas are generally very light and porous in structure.

The two most important calcareous or lime rocks of the crystalline class have already been mentioned, viz:—

44. **Granular Marble**;—a crystalline limestone, generally pure white in color, and composed of glistening grains like loaf sugar.

45. **Dolomite**;—which has almost the same appearance as granular limestone, but which also contains carbonate of of magnesia.

46. **Fragmental Rocks.**—These are much the same as sedimentary rocks; that is, they have been formed by cementing together small particles or fragments of other rocks. The more common are:

47. **Conglomerates or Pudding-stones**;—which have been formed by cementing together very coarse fragments or pebbles of many other rocks. The name of the conglomerate depends upon the kind of the pebbles which principally compose it.

48. **Sandstones**;—generally consisting of fine grains of quartz sand cemented together into compact rock. They sometimes contain other minerals.

49. **Shales**;—rocks composed of compact clay. They have the same variety of colors as the slates. The latter are shales which have been much altered by heat. All shales split easily into thin fragile plates.

50. Limestones; — compact sedimentary rocks, consisting principally of carbonate of lime, but frequently containing small quantities of other minerals. They are generally of a grayish white color, but are sometimes found of a great variety of other colors. The so-called yellow, red, and black marbles are simply these colored limestones polished. When pure limestone is heated or burned, *quicklime* is obtained. If magnesian or impure limestones are burned, they sometimes furnish a *hydraulic cement*, which will harden under water.

III. STRUCTURE OF THE ROCKS.

If we examine the immense rock masses of which the earth's crust consists, we shall find them of two kinds,— *stratified and unstratified.*

51. Stratified Rocks.— This name is given to those rocks which lie in beds or layers; hence their name — from the Latin word *stratum*, (plural, *strata*), which means *spread out.* The earth's rocky strata are spread out in beds of vast extent, many of them covering thousands of square miles. They are the rocks of nearly the whole of the United States and of nearly all North America. (*Dana.*)

52. Strata.—A stratum, then, would be defined as a bed of any one kind of rock. A stratum may be made up of still smaller rock beds or plates, which are called *layers.* A number of strata lying one above the other, which were formed in a particular geological age, is called a *formation.*

Stratified rocks show many interesting varieties of structure. They are said to be:

(1) *Massive*, when it is not possible to split them into thin slabs. *Ex.*—Some varieties of granite.

(2) *Schistose*, when they break easily into slabs because of their crystalline structure. *Ex.*—Mica slate.

(3) *Laminated*, when they may be broken into slabs, but not because of their crystalline structure. *Ex.*—Some kinds of limestone are laminated.

(4) *Slaty*, when they split easily into thin plates. *Ex.*—Roofing slate.

(5) *Shaly*, when they also split readily into thin plates, which are irregular and fragile, inclining to break easily. *Ex.*—Clay shale.

The strata of rocks frequently show peculiar markings, which were produced while they were forming. *Ripple marks* are common, and were produced by the gentle flow of water over the rock bed while it was still soft and unhardened. The prints of *rain drops* are sometimes found, produced while the rock was in the same condition. *Mud cracks* are found in clay rocks, which, in the process of drying, frequently crack and split, the cracks afterwards becoming filled with some other rock material.

53. **Unstratified Rocks.**—Rocks are called unstratified, which do not give any evidence of having been formed in beds or strata. Such are the high trap rocks of Lake Superior and of the Hudson River, and many hills and mountains of granite. Perfectly unstratified rocks are found in but very few places upon the earth's surface. We should expect this, from our knowledge of the manner in which the rocks of the globe were formed. As we have already seen in paragraph 6, after the earth had cooled, and a thick rock crust had been formed, it became nearly covered by the waters of a great ocean, whose waves began to wear away and work over the unstratified rock below. The fine

material, thus produced, would be afterwards distributed by the waters into beds or strata, which would in time, by heat and pressure, be hardened into stratified rock.

Thus, *nearly* all the unstratified rocks of the globe have been covered by those which are stratified. Even granite is supposed to have been at first a stratified rock, which has lost its structure by the action of intense heat. While these stratified rocks are very widely distributed over the earth, they are not all found at any one place, nor are they the same in all regions. Some strata found in one State are unknown in others; and strata formed at the same time may in one State be limestones and in another sandstones.

54. **Vein Structure.**—This is a somewhat uncommon formation, which has been made by the rocks becoming cracked or fractured, and the openings, thus formed, afterwards filled up with other rock material. These veins may vary in thickness from that of a sheet of tissue paper to a width of many yards, and they often contain metals and ores. When these breaks have been filled with melted rock, forced up from below, they are called *dikes*.

55. **Positions of the Rock Layers.**—Nearly all stratified rocks were first deposited in horizontal beds or layers. We know this must have been the case because, as we have already learned, these rocks were formed by the accumulation of fine particles of loose earth, sand, mud, etc., distributed by the action of water, either of the ocean or of lakes or rivers; very much as the deposits we call deltas are now formed at the mouths of large rivers.

In many coal beds, which we know to have once been great marshes, trunks of trees have been found standing erect and always perpendicular to the general strata. There

is one exception to the formation of horizontal strata, which might possibly take place in the case of rivers falling with a sudden pitch into the ocean, when the deposit would of course follow the curve of the river bed.

56. **Upheavals of the Rock Layers.** — Though these rock beds were horizontal when first formed, very few of them are now found in that position. Many of them are sharply inclined, and some even stand upon end. This arises from the fact, that since the formation of these strata they have been tilted up and thrown out of position by great upheavals of the earth's crust. Sometimes these strata are bent upon themselves in immense folds, miles in extent, and frequently they have been broken squarely in two.

When strata lie one above the other in parallel layers, they are said to be *conformable*. But when one set of strata lies horizontally over another set which has been bent or tipped up, the two are *unconformable*.

When the edges of a number of strata are thrust out of the ground, it is called an *outcrop*. The angle which the outcrop makes with the horizon is called the *dip*. The horizontal direction at right angles with the dip is called the *strike* of the strata. (*Dana.*)

A *fault* is where strata have been thrown up, broken in two, and a part displaced either upward or downward. Sometimes where strata have been thrown up in sharply curved folds, the upper portion of the fold becomes worn away, so that there appear to be the edges of two beds in sight, while they are really parts of one formation. In consequence of these great upheavals, we may become very familiar with the entire strata of the earth, and measure accurately both their extent and thickness. If they had all remained in their first positions, this would be impossible; as in that case they would lie far down,

beyond our reach. But no matter how deeply they may have once lain, at some point upon the earth's surface each has been upturned by some great disturbance, and placed within the easy reach of our observation and study.

57. Rocks, the Result of Life. — Many of the important rock formations of the earth's crust are plainly the result of material furnished by plant and animal life. As we shall see hereafter, the immense beds of mineral coal are merely the remains of plants. Many limestone rocks of the globe are on the other hand plainly of animal origin, having been directly furnished through their remains in the form of shells or stony skeletons. This is finely seen in the immense coral reefs of the ocean, some of which are even now being built by the remains of minute coral animals. Numbers of this class of rocks, when examined with a microscope, will show many fragments of little shells. In others, the shells may have been destroyed by the action of heat, or they may have been ground to a fine powder by the wearing effects of water, and have become solid rock. Some other minute animals, and even some plants, have a covering of silica, which, gathering from their remains, forms vast siliceous deposits.

SECTION III.

GEOLOGICAL AGES.

58.—The extensive layers or strata, of which the rock formations of the earth consist, may be regarded as so many pages which make up a history of the changes through which the earth has passed since its creation. The strata, which were formed in any one particular period of time, are grouped together into what is called an *Age*. We may regard these ages, then, as chapters of the earth's geological history. By careful and minute examination of the rock formations over many portions of the earth, geologists have succeeded in making this history very complete and perfect. But it must not be supposed that this could be done by the study of the rocks of any one country, or even of any one continent. We must examine all the rock formations of the earth, as far as they can possibly be reached, before we can arrive at any reliable conclusions.

This is necessary for many reasons. We have already seen that the rock strata of the same period may differ greatly in different countries, or even in different parts of the same country, so that without careful study we should be misled by this variation. Then, too, by the gigantic disturbances and upheavals, of which we learned in the

last section, these strata have been so thrown out of place that we can not often trace them regularly for more than a short distance. In many places the strata have been almost entirely washed and worn away; and nearly everywhere they are covered with the earth and soil, only cropping out here and there. All these conditions make the examination of the strata very difficult, and render it necessary to study them over a great extent of surface.

59. **Fossils.**—The most perfect method of determining the place or age of any rock layer is by the study of the stony remains of the animals and plants which it frequently contains, and which lived and died while the layer was being formed. These plant and animal remains are called *fossils*, a word which means *that which is dug out of the earth*. These fossils have been so carefully collected and studied that by their aid we are able to tell much about the condition of the earth, and of the plants and animals which lived upon it during each age or period.

60.—The geological ages through which the earth has passed have been arranged by Professor Dana as follows:

1st. *Age without Life* (*Azoic*).
2d. *Age of Mollusks* (*Silurian*).
3d. *Age of Fishes* (*Devonian*).
4th. *Age of Coal Plants* (*Carboniferous*).
5th. *Age of Reptiles* (*Mesozoic*).
6th. *Age of Mammals* (*Cenozoic*).
7th. *Age of Man*.

61. **Subdivisions.**—In the study of the strata of these great ages, we find that there are very sudden changes from one stratum to another, which were accompanied by almost entire destruction of some kinds of life, and by the introduction of others. Hence, we can divide some of these ages into smaller portions of time called

periods, and these again into still smaller divisions called *epochs*. We shall now briefly examine the geological ages of the earth's history in their order.

I. AGE WITHOUT LIFE, OR AZOIC AGE.

62.—As its name signifies, this was the age without life; or, if any existed, it must have been of very simple kinds, the remains of which have not been preserved in the rocks. The Azoic rocks are the oldest of the earth's crust, and they surround the entire globe. They are, however, found in few localities, because they have since been covered by the various later formations. The great Azoic area upon this continent is a vast V-shaped tract, extending from a point north of Lake Superior in two great arms north-east and north-west. With the exception of this great area, and a few small spots or islands, the entire continent was covered by the waters of a great and apparently lifeless ocean. The rocks of this age are almost wholly crystalline in nature—granite, mica slate, quartz rocks, and granular limestone. Many large deposits of iron ore were made in this age; such are the great beds of the Lake Superior region, of Iron Mountain, and of Pilot Knob in Missouri.

II. AGE OF MOLLUSKS, OR SILURIAN AGE.

63.—The formations of this age were named from the Silures, an ancient tribe in Wales. The age is divided into two portions, the Lower and Upper Silurian, each of which is separated again into periods.

64. **Life of the Silurian Age.**—The life which first appeared upon the earth during this age must, of course, have been of the simplest and lowest kinds, and belonged wholly to the ocean. The greater part of this continent was under the shallow waters of a wide ocean, and there were no land plants or animals. The plants of the age were all *sea-weeds*. The animals varied slightly during the different periods, but were all sea animals. They consisted of *radiates*, such as corals, star-fishes, etc.; *mollusks*, soft, pulpy animals, usually with a shelly covering, such as our river muscles, snails, etc., some of them of immense size, having shells ten to fifteen feet long; *articulates*, or jointed animals, the most remarkable of which were the trilobites, some of them twenty inches in length; and peculiar, lobster-like *crustaceans*, growing from six to eight feet long. *Sponges* were also abundant, and trails of *worms* are found upon the rocks of this age.

65. **Rocks of the Silurian Age.**—(*a*) *Lower Silurian.*—It is probable that, excepting the azoic areas of ancient land, the Lower Silurian strata cover nearly the whole of this continent, although they are often hidden by other formations. Over the interior of the continent, the rocks were sandstones below, and magnesian limestones above; while over the eastern portion, the formation was principally slate. The sandstones contain ripple marks, and the slates, mud cracks, showing that much of the continent lay at the bottom of a shallow sea, either as a sandy bed or beach, or as a mud flat or bottom. The second period of the Lower Silurian was one of the limestone periods of the continent. During the first portion of this period, limestones were forming not only over the eastern portion, but over the whole of the interior continental region. Some of these limestones were afterward

much altered and crystallized by heat, and now constitute the marble quarries of Vermont and Massachusetts. During the third period, the region of limestone making decreased in size, and over the eastern part of the continent, as well as the northern portions of the interior, the formation of shales and shaly sandstones began; while, in other parts, shales and shaly limestones were formed.

While through all these periods gentle and gradual changes of level were going on in the earth's crust, more important upheavals took place about this time. Near Lake Superior, about the close of the first period, the rocks became widely fractured, and large quantities of melted rock were forced up, forming the immense trap-dikes which are seen there to-day. The Green Mountains, the first of the Appalachian Range, now appeared above the level of the ocean as dry land.

(*b*) *Upper Silurian.*—There was a great variety in the rocks of the first period of the Upper Silurian. They were: 1st. A conglomerate rock, extending from Central New York south to the Appalachian Range. 2d. A soft sandstone, extending in the same manner, but still further westward, across Michigan. 3d. A hard sandstone, extending further west still. 4th. A deposit consisting of limestone, over the interior of the continent; shale below and limestone above, at Niagara; and shales and limestone over the Appalachian region. The rocks of the second period of the Upper Silurian are loose sandstones and shales, reddish in color, occurring over New York and a little to the westward. It is from this formation that the rich salt brines of New York are obtained. The rocks of the third period of the Upper Silurian are impure limestones, confined to New York and the Appalachian

region. At the close of the Silurian age, half of New York and most of Canada and Wisconsin had become dry land. Michigan was still under water.

III. AGE OF FISHES, OR DEVONIAN AGE.

66.—The formations of this age were named after the principal rocks in Devonshire, Great Britain. The age is remarkable for the first appearance upon the globe of land plants, of insects, and of fishes. The latter were the first vertebrate animals, or those having a backbone.

67. **Life of the Devonian Age.**—The most remarkable plants of this age were enormous ferns, lycopodiums (ground pines), tree rushes growing over twenty feet high, and trees closely resembling our modern pines. The animals of the age included many forms similar to those of the preceding ages; but the age was especially interesting for its immense coral formations, the greatest in the earth's history. Here also are found the first insects. The fishes, which here first appear, belonged to the two classes:—the selacians or sharks, and the ganoids or sturgeons, gar-pikes, etc. Some of the last class were of great size, and their appearance at this early time is of great interest, inasmuch as they present many peculiarities of structure, which seemed to foreshadow the varied forms of vertebrate life that were to appear in the geological ages to come.

68. Rocks of the Devonian Age.—The rocks of this age may be included in the formations of five periods:

1st. A sandstone (the Oriskany), stretching from the Appalachian region northward into New York and westward to the Mississippi, where it is represented by a limestone deposit.

2d. A formation consisting of a layer of grit rock below, and an upper layer of coral-formed limestone, extending from New York westward beyond the Mississippi (Corniferous.)

3d. A formation of sandstone and shale, and layers of limestone; also extending from New York westward, where it exists mainly as limestone. (Hamilton.)

4th. Principally consisting of sandstone, over Southern New York. (Chemung.)

5th. Comprising the sandstones and shales of Pennsylvania. (Catskill.)

IV. AGE OF COAL PLANTS, OR CARBONIFEROUS AGE.

69.—This age is named from the great coal beds which it contains. The rock strata of the age show that, in its first portion, the continents were almost wholly covered by seas. That, in the next period, there was an elevation of a part of the land above the sea level, forming immense stretches of marshy country, which were covered with a luxuriant growth of vegetation, where the coal beds were formed; but that, even at this period, there were alternate elevations above water level, and depressions below it, as shown by the coal being in seams, alternating with other marine rock strata. Finally, in the closing period, the oceans again covered much of the land, though not to so great an extent as in the preceding ages.

70. Life of the Carboniferous Age.—The great marshy districts and floating islands of the Carboniferous age were covered with a wonderfully dense growth of vegetation, mostly of flowerless plants; tree ferns, growing to the height of twenty feet, lycopodiums, and tree rushes. Among flowering plants, there were trees related to our

pines; and great trees, called *Sigillarids*, growing to a height of sixty feet. Remains of fruits and nuts have also been found. Among the animals also, of this age, there appeared to be much progress. Besides insects, there existed centipedes and scorpions; and among vertebrates, in addition to the usual variety of fishes, there were found, for the first time, reptiles, as shown by their remains and foot-prints found in the rocks.

71. **Rocks of the Carboniferous Age.**—The rock strata of this age are divided into three periods:

(*a*) *Lower Carboniferous.*—Over the interior of the continent, the rocks of this period were mostly limestones, while, upon the eastern border, they were sandstones and marls, with some limestones.

(*b*) *Upper Carboniferous Period.*—The formations of this period were sandstones, shales, conglomerates, and limestones. Between these strata occur the seams of coal in occasional beds; but the entire coal seams, taken together, are not *one-fiftieth* of the thickness of the formation.

(*c*) *The Last or Permian Period.*—These rocks are mainly sandstones and impure limestones, with some gypsum. They cover many portions of the interior, especially in Kansas, and occasionally contain thin seams of coal.

72. **Coal Formations.**—As already stated, the indications are plain that this age was one of numerous changes of level; that all regions, over which the formation of coal was going on, were at long intervals of time depressed below the sea level, so that coal forming was for the time checked, and layers of marine rock were deposited; that when the land was again elevated to the condition of a marsh, the thick growth of vegetation and the making of coal began again, and thus there were formed alternate coal beds and marine rock layers. The

extent of the coal deposits over the earth show that the *climate* of the age was wonderfully adapted to plant growth; the atmosphere was warm and uniform, and laden with moisture. Coal beds were formed by the accumulation of vegetable matter, which was afterwards partly decomposed under great pressure.

Over these great coal marshes were constantly gathering fallen leaves, dead parts of plants, etc., after long ages, making deposits of great thickness. By the pressure of the mass above, the layers below, while slowly decomposing, were forced into a more compact state. Finally, when the entire region became lowered, the ocean overflowed it, and thick beds of marine rock were for ages formed above it. The immense pressure and smothered decay forced out the light gases of the vegetable matter, and left behind a bed of nearly pure carbon or coal. A depth of from eight to twelve feet of vegetable matter would be needed to make one foot of coal. Coal beds vary in thickness from a fraction of an inch to over forty feet. These beds sometimes contain large erect trunks of trees changed to coal. The kind of coal depends somewhat upon the extent to which the pressure has been carried, and upon the heat to which the bed may have been exposed. *Bituminous coal* is that containing much bitumen, or pitchy substances; it burns with a bright flame. *Anthracite coal* is a hard, compact variety, with little or no bitumen; it produces great heat, but very little flame. *Cannel coal* is a compact, bituminous variety. The rock layers just above and below coal beds are frequently soft shales—those above often being full of impressions of leaves and twigs.

V. AGE OF REPTILES, OR MESOZOIC AGE.

73.—This age is named from the immense number and great size of the reptiles which then existed. It is divided into three periods, Triassic, Jurassic, and Cretaceous.

74. **Life of the Reptilian Age.**—Among plants, there were found in the first two periods (the Triassic and Jurassic) the usual ferns and tree rushes, but especially a new group of trees, called *cycads*, which somewhat resemble the palms. In the third period (the Cretaceous), there was an abundance of true palms, besides the sassafras, willow, oak, beech, etc. The animals of the first two periods of this age contained the first *birds* and low orders of *mammals*, or warm-blooded animals. But the great feature of the age were the reptiles, which were of enormous size and great variety. Many of them (Ichthyosaurs and Plesiosaurs) attained a length of over thirty, and sometimes as great as seventy, feet.

There were also species of flying reptiles, with wings like bats. One of these (Pterodactyl) had a spread of wings of over ten feet. The birds of these two periods must also have been of great size, as some of their tracks were over two feet long. Some of these birds had long tails like reptiles, with the feathers arranged upon each side. In the third period (the Cretaceous), there appeared, for the first time, fishes related to our modern species, similar to the perch and pickerel.

75. **Rocks of the Reptilian Age.**—The rocks of the first two periods consist principally of sandstones and conglomerates, shales and limestones. In many places, the sandstones of these periods have been strongly fractured, melted rock forced up, and great trap-dikes formed.

Large beds of gypsum were also formed during these two periods over the interior of the continent. The rocks of the third period (the Cretaceous) extend over a large region west of the Mississippi. The Cretaceous was the great *chalk* period of Europe, but it was long supposed that no true chalk existed upon this continent. Fine deposits have, however, been lately discovered in the western portions of Kansas. It differs from foreign chalk in having no traces of flint. During this period, the celebrated *green sands* of New Jersey were deposited. There must have been toward the close of this age a marked increase of dry land, especially over the western interior of the continent.

VI. AGE OF MAMMALS, OR CENOZOIC AGE.

76.—This age receives its name from the great number, variety, and enormous size of the mammals (or warm-blooded animals) which then flourished. It contains two periods, the Tertiary and Post-Tertiary.

77. **Life of the Mammalian Age.**—The plant life of this age includes still more of the same class of plants which first made their appearance in the age preceding. Many remains are found of the leaves of the hickory, maple, mulberry, sycamore, etc., beside those of palms and pines. Among the animals of the first, or Tertiary, period, there existed many reptiles, such as the crocodile and turtle, a shell of one of the latter having been found over twelve feet long. Birds were also abundant, not of the reptilian kinds, but true birds, much like those found to-day. The mammals were even more remarkable. Whales lived in great numbers in the ocean. Upon the land, there were species of the tapir, as large as a horse; the elephant,

camel, horse, deer, wolf, etc., also existed, many of them having several species.

It was in the next or Post-Tertiary period, however, that this class of animal life became most remarkable, both for the number of the species, and for the size of the animals themselves. Among them was the great Irish elk, whose height was eleven feet, with the spread of the antlers eight feet. The elephant of that period was fully one third larger than at the present day, tusks having been found over twelve feet long. One of these elephants, which was found preserved in the ice in Siberia, had a coat of long hair. The mastodon of that period was of enormous size; the skeleton of one, found in New York, was eleven feet high and seventeen feet long. In South America, there was a great sloth, called the megatherium, eighteen feet in length; also, an animal similar to the modern armadillo, nine feet in length, and covered with a great shell. From the very wide distribution of the animals of the earlier period, we know that the climate over the entire globe must have been much warmer and more uniform than we find it to-day.

78. **Rocks of the Mammalian Age.**—The deposits of the first or Tertiary period in America were not, generally, solid rock. They consist principally of compacted sand, clay, and earth, formed by the action of water, very much as such deposits are now made. There were also formed some loose coral limestones. A hard, siliceous rock, called *burr-stone*, now used for millstones, belongs to this period. The Post-Tertiary period was the great soil-forming era of the earth's history. It is divided into three epochs:

(*a*) *The Glacial Epoch*—during which, by the action of great fields of moving ice, there was a vast transportation

of earthy material from northern to southern latitudes over a large extent of the United States. This deposit of earth and stones is called *drift*. It extends over much of the Northern States, westward as far as into Kansas and Nebraska, and south as far as Southern Ohio and Indiana. We shall study fully, in Part II, the action of these glaciers upon the rocks.

(*b*) *Champlain Epoch*—during which there were three classes of formations going on: 1st. *Alluvial*, formed by the waters of rivers, as they bore along earthy material in their currents, and distributed it upon their overflow beds. 2d. *Lacustrine*, deposits formed by the action of waters of lakes. 3d. *Sea Border*, similar deposits along ocean edges, appearing like elevated beaches.

(*c*) *Terrace Epoch*—when, in consequence of the gradual elevation of the earth's level above the water line, the streams cut the alluvial formations into great terraces; and the sea border formations were cut into plains of different level by the gradually receding waters in the same manner. The river terraces along the Connecticut show this formation very perfectly. Thus, the first period of this age enlarged still further the limits of dry land, while the second period brought the surface of the earth into proper condition for the coming age of man.

VII. AGE OF MAN.

79.—The geological ages of the earth's history now reach their culmination in this, the *Age of Man*, of which our own time is but a continuation. As the events of all the preceding ages were plainly but a long preparation for the present age, so the whole chain of animal

creations was finally completed by the appearance of man, as the most perfect type of the animal kingdom.

80. **The Life of this Age** differs in important respects from that of the ages which preceded it. In some classes of animals, especially in birds and insects, our age probably excels all others in the number of its species. In reptiles and mammals, it falls far behind, and the ocean life of this period is much inferior to that of the preceding ages. Many species have become extinct, having been destroyed by man, and others are fast disappearing through the same agency.

Thus, there existed upon the island of Mauritius until the close of the 17th century a huge, clumsy bird, called the *dodo*. Its body was covered with down, and its wings were so short and feeble, as to be useless for flight. This bird is now utterly extinct. The *buffalo* once abounded over nearly all the plains of the United States; but it is now being each year hunted and driven nearer the Rocky Mountains, and promises soon to become extinct.

While there are many evidences to show that man first made his appearance upon the earth during the terrace epoch of the age of mammals, the exact time of his first existence must be regarded as very uncertain, as the discoveries of geologists constantly tend to remove that time to a still earlier period of the earth's history.

81. **Rock Formations of the Age.**—Deposits of rock material are constantly going on now, as they have been in past ages. These deposits are either *alluvial*, by the action of rivers, *lacustrine*, by that of lakes, or *sea border*, by the ocean. Many of the forces, so powerful in the past age, are now in operation. Glaciers are still found over many portions of the earth, especially upon mountain ranges, crushing and grinding the rocks to earth.

The glaciers of the Alps alone number over six hundred. Over many marshes also, deposits of vegetable matter are being made in a manner very similar to those of the carboniferous age, forming large beds of *peat*. In some of our western States, but especially in Michigan, these peat beds are of enormous extent, covering thousands of acres, and measuring over thirty feet in depth. Changes of level are also constantly taking place in this age. These changes are either *paroxysmal*, as in the case of earthquakes, or *secular*, as in the slow elevation or depression of long stretches of coast line in many countries.

82. **Lengths of the Geological Ages.**—It is, of course, impossible for us to know the absolute length of time in each of these ages of the earth's history. We only know that they were immensely long, covering periods of time which can hardly be numbered by years—periods so long that we can hardly conceive of them. Geology simply declares: *Time is long.* But it is possible for us to obtain some idea of the *relative* lengths of these ages. This we can do by comparing the thickness of the various rock formations which each age presents.

If we proceed in this manner, we may divide the stratified rocks of these ages into three eras,—the first, including the age of mollusks, age of fishes, and age of coal plants; the second, the age of reptiles; and the third, the age of mammals. Then, the relative lengths of these three eras will be to each other as the numbers 14, 4, and 3. That is, the earliest period of the earth's history, when life was of the lowest order, was by far the longest. The *Age of Man*, while it includes within its limits all the great events of human history, sinks into utter insignificance when the absolute length of its time is compared with the vast periods which have preceded it.

TABLE OF GEOLOGICAL TIME.

	AGES.	PERIODS.	EPOCHS.
	Age of Man.		
Cenozoic Time.	Age of Mammals.	Post-Tertiary.	Alluvial.
			Bluff.
			Champlain.
			Glacial, or Drift.
		Tertiary.	Pliocene.
			Miocene.
			Eocene.
Mesozoic Time.	Age of Reptiles.	Cretaceous.	Fox Hills Group.
			Pierre "
			Niobrara "
			Benton "
			Dakota "
		Jurassic.	Wealden.
			Oölite.
			Lias.
		Triassic.	New Red Sandst , (Saliferous.)
Paleozoic Time.	Carboniferous.	Permian.	Permo-carbonifer.
		Upper Carb.	Upper Coal-meas.
			Lower Coal-meas.
		Lower Carb.	Chester limestone.
			St. Louis "
			Warsaw "
			Keokuk "
			Burlington "
			Kinderhook beds.
	Devonian, Age of Fishes.	Catskill (Old Red Sandstone).	
		Chemung.	
		Hamilton.	
		Corniferous.	
		Oriskany.	
	Silurian, Age of Mollusks.	U. Sil. Era.	Lower Helderberg.
			Salina.
			Niagara.
		L. Sil. Era.	Trenton.
			Canadian.
			Primordial.
	Azoic, or Archæan.		

SECTION IV.

I. THE GEOLOGY OF KANSAS.

83.—Kansas has an average height of about 2,300 feet above the level of the sea. The surface geology of the State has been explored by Professors Mudge, Cope, Marsh, St. John, and others; and although our knowledge is not yet sufficient for us to be able to accurately define the outlines of every formation, we yet have a very good general idea of their extent. These formations have been most perfectly explored by Prof. Mudge, and we shall trace them as mapped out by him from the earlier periods down to the present, beginning with the eastern boundary of the State.

84.—For our own convenience, we can classify the formations of Kansas as follows:

AGES.	PERIODS.	EPOCHS.
	Age of Man.	
Cenozoic Age.	Post-Tertiary.	Alluvial. Bluff. Drift.
	Tertiary.	Pliocene.

AGES.	PERIODS.	EPOCHS.
Mesozoic Age.	Cretaceous.	Niobrara. Dakota.
Carboniferous Age.	Upper Carboniferous.	Permo-carboniferous. U. Coal-measures. L. Coal-measures.
	Lower Carboniferous,	Keokuk limestone.

These come to the surface in different portions of the State, because the later formations do not completely cover the older ones, but overlap them. Making our starting point with the oldest formation, we have:

85. The Lower Carboniferous.—This covers a very small triangular-shaped tract, cut off by the Spring River, from the extreme south-east corner of the State. It extends six miles on the Indian Territory and ten miles along the Missouri line. (See part of the map colored purple.) It is really a continuation into Kansas of a similar formation, existing over the adjoining territory in Missouri, and is the only part of our State that contains metallic deposits of any importance, furnishing ores of zinc and lead. Its strata are apparently made up of limestone and siliceous material, in the condition of *chert*, a variety of flint. They are in places crowded with fossils, which plainly show the identity of the formation with the Keokuk limestone. The strata of this formation have been considerably disturbed and thrown out of position.

86. The Lower Coal Measures.—The productive or lower coal measures of this State outcrop at the surface over several of the south-eastern counties, the exact limits of which area are not as yet clearly defined. According

to Prof. Mudge, its south-eastern border is defined by the Spring River, which separates it from the small region of the Lower Carboniferous in the extreme south-eastern corner of the State. (See the part of the map colored green.)

In this more or less irregular triangular area, several distinct coal beds are known to exist, the thickest of which is above four feet. In Cherokee and Crawford counties, the coal appears at the surface and is easily and extensively mined. The bulk of the strata of this lower coal formation consists of sandstone, sandy shales, and clay shales, with occasional deposits of earthy limestone.

In connection with some of the coal beds, the shales often preserve beautiful specimens of the plants which flourished during this epoch, and whose remains were finally converted into mineral coal. Also, in some of these sandstone deposits are found the remains of gigantic club-mosses and equiseta, — plants, whose modern representatives, now growing in the soil above these ancient and prostrate forests, are, in comparison, very insignificant and diminutive. Among animals, a few insects existed, and aquatic animals were abundant in the lagoons of the ancient forests. But, as we have already learned, these coal-forming areas were undergoing alternate submergence below water level and elevation above it; and during the former condition, when the seas had taken possession of the land, they were peopled with a vast variety of marine life, whose remains are now so abundant in many of the strata forming our coal measures.

87. Permo-carboniferous and Upper Coal Measures.— The relations of these two formations in Kansas are so intimate, that we shall consider them together.

They cover an area of about 20,000 square miles. The western boundary of this region may be rudely traced by a line starting from the Nebraska border on the north, and extending in an irregular south-western course through Clay County, and on through the Arkansas valley, crossing it in Reno County. All points east of this line, not included in the formations of the two preceding periods, are Permo-carboniferous and Upper Coal Measures. (See the part of the map colored yellow.) The rocks of the upper member consist mainly of clay, limy clay or shales, limestones, and extensive deposits of gypsum. The limestones afford admirable building material. The Permo-carboniferous beds furnish no coal in Kansas. The deposits of the Upper Coal Measures are very similar to those of the preceding member, with, perhaps, more sandy materials. They contain few coal veins of sufficient thickness for mining, and those which have been reached by boring through the strata are at a great depth, and belong to the productive or Lower Coal Formation.

88. The Cretaceous.—The formations of this period extend over by far the largest portion of Kansas, covering an area of about 41,000 square miles. (See portion of the map colored blue.)

We have already traced the eastern boundary line of this period, separating it from the Upper Carboniferous. All west of that line belongs to the Cretaceous, except a small tract in the north-west corner of the State, which would be cut off by a line starting from the Nebraska border, in Smith County, and extending irregularly south-west to the Colorado line, in Wallace County. The rock materials of this period are limestones, sandstones, shales, and marls, with deposits of genuine chalk. The western group of this period (the Niobrara) has furnished collectors

with a wonderful variety of vertebrate fossils — fishes, reptiles, birds, etc. It has not only added a large variety of species not known elsewhere, but has also revealed many intermediate types of animal life, which have greatly extended our knowledge of the life-history of the globe.

89. **The Tertiary.**—The north-west corner of the State, cut off by the line already described, belongs to the Pliocene epoch of the Tertiary period. (See the part of the map colored red.) The separation between the Cretaceous and Tertiary formations, though clearly defined, is hardly a sharply traced line, but rather a stretch of country, thirty miles wide, extending across the State from Nebraska to Colorado. Within this band may be found the formations of both periods, the Cretaceous, in the low valleys, and the Tertiary, upon the high hills. The rocks of the Tertiary period are generally crumbling sandstones of various colors, overlain with beds of coarse pebbles, etc.

90. **Post-Tertiary.**—The formations of the last or Post-Tertiary period are much the same in Kansas as elsewhere. On the eastern border of the State, along the Missouri River, are good specimens of the bluff formation, which is identical with that found in similar localities in Missouri, Iowa, and Nebraska. It is composed from top to bottom of fine earthy material, with little or no coarse matter. It is undoubtedly due to the accumulation, just after the glacial epoch, of immense deposits of fine sediment and silt, before the present channel of the river was cut.

The alluvial deposits of Kansas are very similar in character to those found elsewhere, forming the rich bottom lands of our river valleys. Though no marks or scratches upon the rock formations of Kansas have yet been found to show the action of glaciers during this period, yet accumulations of genuine drift and debris are found throughout

the north-eastern portion of the State, where they occupy more or less isolated areas, and are evidently the remains of a once extensive deposit. Large bowlders of foreign rock, or *hard-heads*, can be seen at many points on both sides of the Kansas River, and in various other localities, particularly in Pottawatomie County. These bowlders are generally a quartzose rock, of a pink or reddish color, and are often highly polished. They have probably been transported from the great Azoic areas of Minnesota and Dakota.

II. MINERAL RESOURCES OF KANSAS.

91. **Coal.**—The coal of Kansas is wholly bituminous, or soft coal, and some of its better varieties compare favorably with the shaft coal of the eastern coal-producing States. It frequently has distributed through it, in seams and layers, considerable calc spar, sometimes called *tiff* by miners. This does not injure it for use as a fuel, but simply adds useless matter to its weight. Some inferior varieties, however, contain quantities of iron pyrites,—called *fools' gold*. When such coal is wet and exposed to the air, it frequently takes fire of itself, from the rapid oxidation of the pyrites.

At the present time, there are in this State three principal coal mining centers, situated at more or less remote points from each other. 1st. In the extreme south-eastern portion of the Lower Coal Measure formation, one of the principal beds, which outcrops in many localities, is being worked both by shallow shafts and by *stripping*, that is, removing the overlying soil and exposing the coal. The product of this bed is largely used in smelting the lead and zinc ores brought from the neighboring Lower Carbon-

iferous region, and is also sent to all portions of the State. 2d. At Fort Scott, another and higher coal bed is reached by means of shafts, from which large quantities of coal are shipped to parts of this State and of Missouri. Much of it is colored red by the oxide of iron. 3d. The coal mined in Osage County forms a deposit fifteen to thirty inches thick; it is of excellent quality, and is distributed along the railway lines passing through this district. In addition to these areas, also, at Leavenworth a coal bed is being worked by a shaft at a depth of between 600 and 700 feet. At Topeka, a little coal seam, ten to fourteen inches thick, is now being mined, the product of which is entirely consumed by local demand.

There are probably many other localities where coal is mined to a greater or less extent; but those given are sufficient to show the territory from which the principal coal supply of the State is obtained. Coal, sometimes of fair quality, is found at detached points over the Upper Coal Measure area of the State, but rarely in marketable quantities. In the Dakota group of the Cretaceous area, there is found over the north-central portions of the State a very inferior variety of coal, called *lignite*. It is obtained by stripping, and answers the purpose of a cheap but inferior fuel.

92. **Limestone** is found in great quantity, and of very superior quality, in nearly every portion of the State, except over the area of the Dakota group, and in the extreme north-west. It is found in layers, which are very easily worked, and forms the cheapest and handsomest building material which the State contains. The purer varieties, when burnt in kilns, form a very superior article of quick-lime. At several points in the State, especially at Fort Scott, Leavenworth, and Lawrence, the composi-

tion of the limestone is such that it furnishes, on burning, a very excellent grade of hydraulic cement, equal to the best cements found in the market.

93. **Chalk.**—Until lately, it has been supposed that no true chalk existed in America; but in the last few years, immense deposits of a fine, white variety have been discovered in the Cretaceous formations of western Kansas, which promise to prove of great value in the manufacture of cements.

94. **Sandstone** abounds in various localities throughout the State, especially in the Dakota group of the Cretaceous formation, and forms a valuable building material.

95. **Flagging Stone**, suitable for pavements, is found at various points, but particularly in Osage County, where there are extensive quarries.

96. **Gypsum** is found abundantly in many portions of Kansas. Sometimes it is in beautiful, transparent crystals, when it is called *selenite.* A very large deposit of gypsum extends north of the junction of the Big and Little Blue rivers. The product of this bed is ground extensively in mills erected for the purpose.

This valuable mineral is a compound of sulphuric acid, lime, and water. When simply ground, it is called *plaster*, and is a very valuable fertilizer. When this plaster is heated or *boiled*, to drive off the water, it forms *plaster of Paris*, and is used for hard finish and stucco work in buildings.

97. **Salt.**—Salt is almost invariably found associated with gypsum, and, as might be expected, the salt resources of Kansas are of immense extent; when fully developed, it will be a source of great wealth. Salt marshes are found at various points throughout the State. In the south-western portion, and extending into the Indian Ter-

ritory, is an enormous deposit of fine, white, crystalline salt, in some places over two feet thick. It lies upon the surface of the ground, and has probably been formed by the drying up of an interior salt lake. The salt region proper has been defined by Prof. Mudge as covering a tract thirty-five by eighty miles in extent, stretching across the valleys of the Republican, Solomon, and Saline rivers. Through this region, salt springs and marshes are found frequently in the midst of a very fertile farming district. Salt wells have been sunk at several points by boring. One of the most productive of these wells is at Solomon City.

98. **Metallic Ores.** — The only portion of Kansas that can be considered at all productive in metallic deposits is a section in the south-east, in the counties of Linn and Cherokee, where the geological formation of western Missouri extends into this State for a short distance. Through this region, the common ore of lead, called *galena*, and that of zinc, called *black jack*, or *zinc blende*, have been mined somewhat extensively; but it is doubtful if with any very great profit. The galena, here as nearly everywhere, contains a minute quantity of silver.

Some of these mines were worked long before the settlement of the country, as some suppose, by the Indians, but more probably by the early French miners of Missouri. On account of the abundance of coal in this region, the ores are frequently hauled twelve or fifteen miles from beyond the Missouri line, and smelted here with great profit. Small deposits of lead and zinc ore are occasionally found in other portions of the State in little *pockets*, but never in quantity.

99. **Iron Ore**, of the *brown hematite* variety, is found at a few points in the State, and, though of good quality, is so small in quantity, as to prove of no importance.

PART SECOND.

ORIGIN AND FORMATION OF SOILS.

ORIGIN AND FORMATION OF SOILS.

SECTION I.

CONVERSION OF ROCKS INTO SOILS.

100. **The Soil**, which nearly every-where overlies the rock strata of the earth, is of special interest to us all, because, in the growth and cultivation of crops, it is the only element within our control. The light and heat from the sun, and the rain from the clouds, are entirely beyond our reach; but we have the power, within certain limits, of so controlling and influencing the soil, as to greatly increase its fertility. It is very important, then, that we should understand fully its origin and composition, and the manner in which it has been formed.

All soil was once solid rock. It has been formed by the grinding of these rocks into small fragments, or fine dust, by the action of various forces. The finest soil, when examined by the microscope, will be found to be made up of the little fragments of a great variety of rocks and minerals. While the entire mass of the soil, taken together, seems of enormous extent, yet when it is compared with the mass of the globe itself, it is really little more than a slight coating of dust spread over its outside surface.

We shall now study the great forces which have converted the barren rocks into fertile soils.

I. CHANGES OF TEMPERATURE.

101.—(*a*) We have seen that the earth must once have been a melted mass, and that, in cooling, it became covered with an outside crust. We have also learned that this process of cooling was one of tremendous contraction, by which the earth's surface was thrown up into hills and mountain ranges, with wide valleys and low lands between. But, besides these general effects, this great force of contraction would produce others. The crust of the earth would be broken and fractured in many places, and the masses of rock, crushed upon each other, would tend to grind themselves into small fragments.

Again, many of the earth's rocks consisted of crystals of different minerals, combined together to form the whole rock mass. Now, these crystals would not only expand and contract unequally under the change of the temperature, but each crystal would expand or contract unequally in different directions, so that, in these changes, they would tend to split off from each other, and into small fragments.

(*b*) Water in the rocks frequently becomes a most powerful force. In freezing, water expands fully one fifteenth its bulk, and this force of expansion is so great that nothing known is strong enough to resist it. Hence, along the base of cliffs and mountains, there are always found great piles of rock fragments, split off from the rocks above by the force of frost. In the same manner, this force acts upon the surface of the rock itself, crumbling it into fine dust. If a piece of limestone, for example, be wet with water, and exposed to a hard frost over night, its surface will be found the next morning, upon exami-

nation, to be covered with a minute coating of *mud*, from the particles split off by the frost. The *heaving* action of the frost in the winter and spring still further crumbles the rock fragments of the soil.

II. MOVING WATER.

102.—Water in motion is one of the most powerful forces known in converting rocks into soils. By the heat of the sun's rays, water from the ocean, from smaller bodies of water, and from the earth itself, is converted into an invisible vapor, which rises into the upper regions of the air, where it floats and becomes visible as clouds. These upper regions are much cooler than the lower air, and, hence, these clouds are constantly depositing their moisture in the form of rain and snow. Mountains, by their effect on the currents of air, act as condensers of vapor, and the water gathers rapidly upon them into rills and rivulets; these, uniting, form mountain torrents, until, finally, we have the great rivers, flowing back to the sea. Through its whole course, this moving water exerts an immense wearing power upon the rock bed beneath. At every point, small particles of solid rock are worn away, the little rills cutting their way almost imperceptibly, while the mountain torrents rush down with great power, tearing away large rocks in their course. Every particle thus removed and those which fall into the current from the rocks above add to the wearing power of the water. These rock fragments, carried along by the current, constantly grind, not only the bed below, but also each other to a fine powder. As a result of this action, pebbles, brought down by means of water, are rounded and polished. Sand frequently becomes so water-

worn that its sharp angles are all destroyed, and it becomes useless for masonry work.

The enormous wearing power of water through long ages is well shown in the great canoñs of the Colorado River, where gorges have been cut in the solid rock to the depth of 6,000 feet, simply by this means. The wearing action of streams is, of course, greatest upon the steep inclines of the uplands, where the current is strongest. When the stream reaches more level and lower land, its motion becomes slower, and the coarse pebbles and gravel are dropped upon its bed, while the fine matter, called *silt*, is carried on and generally deposited upon the *flood ground* of the river; that is, where it overflows its banks in high water. It is thus that the rich bottom lands of our valleys are formed. But in some cases, this fine earth is carried still farther on, and is only dropped when the river reaches the sea; it then forms a great tract of marshy land at the mouth of the river, called a *delta*. The delta of the Mississippi covers over 12,000 square miles, and the amount of silt yearly carried down by this river would make a bed of soil one mile square and 268 feet deep.

By the continual wearing away of the rocky uplands, and their conversion into fine earth, the continent is becoming slowly lowered in height, and its spread-out material is extending into the sea. But the wearing action of water does not cease when it has reached the ocean. The ocean's waves, currents, and tides are ever wearing away the rocks along the coast. This, of course, tends to straighten coast lines, by wearing away the headlands, and filling up the bays and inlets. Great oceanic currents, like the Gulf Stream, doubtless accomplish much of this wearing action, although their effects can not be easily seen or understood.

III. MOVING ICE.

103.—Ice in motion was at one period of the earth's history an all-important force in converting rocks into soil. This force is in action, at the present day, in some places, though to a much more limited extent than formerly. *Glaciers* are simply huge mountain rivers, in which the water is in the state of ice, and which, instead of flowing several miles an hour, rarely move more than a foot a day. Glaciers have their origin only upon the summits of very high mountains, far up above the region of perpetual frost, where water can only fall in the form of snow. The latter, by its own pressure, becomes converted into ice, and the mass of ice and snow finally increases to such an extent, that, by its weight, it is forced down the mountain's side through some gorge or valley. It then becomes a slowly moving ice river, or glacier, which is constantly fed by supplies of ice and snow from the regions above.

The first movement of the glacier, as stated above, is due to its own weight and pressure; but as it comes down below the line of perpetual snow, its mass becomes penetrated in every direction by water, which, as it freezes and expands, aids powerfully in forcing it onward. The glacier moves most rapidly in its center, its bottom and sides being held back by friction against its rocky bed. It moves downward, until it reaches a limit where it can no longer exist as ice—generally from a half a mile to a mile below the snow line—when it gradually melts away, and disappears as a river. Ice has the peculiar property, when its broken fragments are placed together, of freezing into a solid mass. By this property, the glacier is able

to fit itself into the inequalities of its bed, by continually crushing and freezing together again. As it moves over the ridges and mounds of the valley which forms its bed, it often breaks nearly across, forming great cracks, called *crevasses*. From the cliffs above, there are constantly falling on the surface of the glacier earth, stones, and rocks, split off by the action of frost. These substances naturally gather near the borders of the glacier, where they form, what are called, *moraines*.

The main glacier, in its course down the mountain, is frequently joined by others; and, as they come together, the accumulations upon their inner edges are united into a double moraine nearer the center. Thus, by frequent additions, the main glacier, towards the lower end, appears like a confused mass of earth, rocks, and ice. In its progress down the mountain, this glacier, of course, exerts an enormous wearing power. Large blocks of rock which fall into the crevasses gradually work their way to the bottom, by the slow twisting motion of the glacier; there they are firmly held by the ice, and, as the glacier slowly moves, act as an immense *rasp*, crushing and scraping the rocks beneath into fine powder.

The course of a glacier can always be traced in any valley, through which it has passed, by the appearance of the surfaces of its rocks. The latter are always scratched or grooved, sometimes deeply channeled, and again smoothly polished, by the grinding action of the bowlders held beneath the glacier. The direction of the scratches is always the direction of the motion of the glacier. The blocks of stone, which have thus been held and ground along beneath the glacier, become worn and rounded bowlders. They are finally dropped and distributed over the country by the melting of the ice, and are called *hard-heads*.

During the course of the glacier, the rock fragments of the entire moraine become more or less mixed up with the whole mass, and, by their grinding motion upon each other, are largely reduced to fine earth. Finally, by the slow melting of the extreme lower end of the glacier, the whole immense burden is dropped in a great mass of bowlders, coarse pebbles, and fine earth. But here, from the melting ice, there rises a powerful river, whose waters become loaded with rock dust, which is thus carried on and distributed through the valley. Many such glaciers are in existence and in action at the present day. Those of the Alps, around Mt. Blanc, are especially interesting, and from many of them flow streams, whose waters are so loaded with the rock dust of the glacier that they are as white as milk.

104. The Glacial Period.—As already stated, there was once a time in the earth's history—the *Glacial Epoch* of the *Post-Tertiary Period*—when a large portion, not only of North America, but of Europe, was covered with huge glaciers, descending from the north. The evidences of this period are very plain. We have already learned of the immense deposits of unstratified material, called *drift*, which covers a large part of the United States, extending southward to the latitude of the Ohio River, and westward into Nebraska and Kansas. This drift consists of fragments of every grade, from fine earth and rock dust to bowlders weighing thousands of tons. From the great size of the latter, we know that no other natural power could have carried them but moving ice. By going nearly north, we find the original rock beds, from which these bowlders, and much of the drift generally, have come. In many cases, they have been carried southward over two hundred miles.

The action of these great glaciers is plainly shown on many of the rocks of this region. Where they are exposed, they are frequently found covered with grooves and scratches, showing the direction and force of the glacier; many of the bowlders of the drift are themselves grooved and polished. The glaciers of that period were of such enormous size, that they could not have been confined to the valleys simply; they must have covered the entire region — valleys, hills, and mountains. On the summits of the last, glacial bowlders have been found, and glacial scratches can be seen plainly on the rocks of the Green Mountains, 5,000 feet above the sea. It has been objected that these great glaciers could not have followed the course described, because, from the north pole southward, there is no natural slope down which they could have moved. But this is really no objection whatever; for, as we have already learned, the greatest force which drives the glacier forward is not the force of gravity, but the expansive force of freezing water, working in the mass of the glacier itself.

Glaciers have been the great soil formers of the earth's history, crushing and grinding solid rock into fine earth, and bringing it into condition to be still further distributed by moving water. From an agricultural point of view, the work they have performed is very important. They have brought together the rock material from a large section of country, and have worked it up into earth; thus producing a soil composed of many elements, and possessing great range of fertility. The soil, thus produced in each section of country, would necessarily have a close connection with the nature of the rock beds north of it. Thus we see that the soils of many of our western States contain more *lime* than those of States east, because

the glaciers of this section, in their course, passed over limestone formations of great extent

105. Icebergs.— Ice, in other forms than glaciers, frequently acts as a great carrier of earth and rock material. Icebergs are really portions of great northern glaciers—frequently those from Greenland—which have extended out some distance into the ocean; large masses have then been broken off by the action of the waves and carried southward by ocean currents. When, on coming into warmer latitudes, the ice melts, its immense load of rocks and earth is dropped, and forms a great unstratified bank. The banks of Newfoundland were thus begun, and are each year increasing in size.

106. Ice of Rivers and Lakes.—When rivers become frozen over in the winter, the rocks and bowlders along the shore are frequently frozen in with the ice, and are carried off by it in the high water of the next spring. They are rapidly ground and worn in their progress, and are finally dropped by the melting ice at great distances from their previous locations, forming beds of coarse gravel and earth. Accumulations of earth and rock material are sometimes seen on lake borders at a considerable distance from the shore, and were doubtless carried up by the ice at a time when the waters covered a greater extent of surface than at present.

IV. WEATHERING ACTION OF WATER AND AIR.

107. Air in Motion.—The air itself, by its mere force of motion and its carrying power, is a great agent in the reduction of the rocks to soil. When regular and powerful winds pass over sand beds or bars, the sand is caught

up and whirled onward with much force; and if, in its course, it comes in contact with ledges of rock, it acts as a *sand-blast* of great power. Cases are known, in which ledges of limestone have become so worn by this action of moving sand, that they appear as though they had been washed out with water; even much harder rocks are rapidly worn away, and quartz becomes brightly polished. Some idea of this power may be gained from the fact, that, upon the shores of the ocean, the glass windows of houses frequently have minute holes drilled through them from the constant wearing action of the sands blown against them. By rubbing upon each other while in motion, the grains of sand become *wind-worn*, and as thoroughly rounded as in *water-worn* sand. Where sand is thrown up on the sea's beach by the waves, it is frequently carried by the wind considerable distances. By this means, small bays and harbors are sometimes cut off from the ocean, especially at the mouths of rivers, and, in the course of time, become entirely filled up, covered with a fertile soil, and, finally, with a growth of plants; large tracts of valuable land have been formed in this manner. Sometimes, however, the sand becomes so wind-worn and water-worn, that it simply drifts and gathers into immense hills, called *dunes*, which are constantly shifting their position. These are well seen upon the eastern shore of Lake Michigan, where the sand dunes often attain a height of from forty to sixty feet, and are very ruinous, sometimes covering up houses and entire fields in their course.

108. **Solution.**—We have already studied the conversion of rocks into soil by the mechanical effects of water; that is, by the action of water *in mass*. But water produces other effects of equal importance by its power of *solution*. Even pure water will dissolve many of the ele-

ments of the rocks in small quantities; and its solvent power is greatly increased when the rocks are reduced to powder, as the amount of exposed surface is then much larger. But *pure* water is something unknown in nature. Water always contains other matters in solution, by which its action upon the rocks is greatly increased. The most important of these matters, contained in all natural waters, is *carbonic acid;* it is obtained either from the air or from the decaying organic matter in the soil. Water will ordinarily absorb an amount of carbonic acid equal to its own bulk; but at low temperatures, and under great pressure, it will take up much more.

Water, when charged with carbonic acid, is called *carbonated water*, and has a very marked solvent power upon many minerals, especially on other carbonates, such as limestones, etc. Hence, the waters of all limestone regions are called *hard*, from the quantity of lime they contain. Carbonated water also acts upon other minerals much more powerfully than pure water. Its action is well shown in the waters of mineral wells, which frequently come from a great depth, and contain a great variety of mineral matters in solution. We know that these matters are largely held dissolved by the carbonic acid contained in the water, because, when it is allowed to stand for some time exposed to the air, the free carbonic acid escapes, and much of the mineral matter settles to the bottom as a thick sediment.

Next in importance of the materials found in much natural water, and which greatly increase its destructive effects upon the rocks, are the *alkalies*—*ammonia*, from the air, and *potash* and *soda*, from certain minerals of the soil. Water, which contains the slightest trace of these alkalies, has even a stronger power of dissolving

minerals than carbonated waters, and, up to a certain point, "its solvent power increases with the amount and number of matters dissolved." Thus, all natural waters are constantly exerting their destructive power upon all exposed rocks, rapidly hastening their conversion into soil. Though this solvent effect may, in any one case, seem to be very slight, yet when we remember the immense extent to which it has operated through numberless ages, we can easily understand the great results it has accomplished. Water also operates upon some minerals in another manner, by uniting directly with them, and forming, what are called, *hydrates*. In this condition, they are softer and more bulky, and, hence, more easily reduced to soil. Many minerals are so composed that they are directly acted on, both by water and by the oxygen of the air, and are thus rapidly reduced to powder.

109. **Weathering.** — The united action of all these forces, air, water, and frost, is called *weathering*. When rocks are exposed to this action, they are more or less reduced to soil, according to the nature of the rock, and the extent to which the weathering process has been carried. Quartz rock is the least influenced by weathering of any mineral known; for when exposed for long periods of time, its surface is but very slightly roughened. Other minerals, such as feldspar, are weathered and reduced to powder much more easily. Limestone, when pure, will withstand the effects of weathering for a great length of time; but clayey limestones, and those containing many impurities, are rapidly weathered and destroyed.

V. ACTION OF PLANT LIFE.

110. **Plant Life,** ever since its appearance upon the earth, has exerted a very important influence in the change of barren rocks into fertile soil. We may study this action of plants under two heads:

1st. The effects produced by living plants themselves.

2d. The action of decaying vegetable matter.

111. **Effects of Living Plants.**—We may suppose that, ever since their appearance upon the earth, plants have produced the same effects upon the earth's rocks, as we find them producing to-day. This effect is nicely shown in the first growth of vegetation upon volcanic rocks. When *lava* flows in a melted condition down the side of a volcano, it cools into a hard, barren rock surface. For a long time, no plants can live upon it, except little, microscopic plants, almost invisible to the naked eye, which receive their food wholly from the air. After many years, the weathering action of the air will gather a very thin film of true soil on the hard surface of the lava, and a slightly higher order of plants will begin to appear, mosses, lichens, etc., which, as they die, will increase by their remains the layer of soil. And so, with each generation of plants, this change will proceed, until, finally, the the sterile rock will become a bed of fruitful soil, capable of supporting large trees and of growing farm crops. But, in this process of soil forming, the plants have not acted simply by contributing their remains to the gathered soil, but, with their tiny rootlets, they have attacked the solid rock itself, and assisted powerfully in its destruction.

This action of living plants upon the rocks may be owing, *first*, to the moisture which all growing vegetation

gathers and holds beneath it, and which is a great aid in the formation of soil; and, *second,* to the action of the roots themselves. These are well known to have the power of attacking the rock fragments, dissolving and removing minute portions. Slabs of limestone are frequently found under the soil, with their surfaces covered with a net-work of minute grooves or channels, each being the bed of a rootlet, which has thus eaten its way into the rock. Experiments have been made, by taking pieces of polished stone, such as marble, dolomite, etc., placing them in vessels under sand, and sowing seeds of grain above. The rootlets of the growing plants were seen to descend and spread over the stones below; and the latter, when examined at the close of the season, were found with their surfaces softened and roughened, plainly reduced by the action of the rootlets. Even on hard quartz rocks, mosses have been found growing so firmly that they could not be removed without scaling off the rock, and beneath the surface, the rock was plainly yielding to the plants' action.

This effect of living plants is, in many cases, probably owing to certain organic acids which the roots contain, by means of which they are able to dissolve and remove a minute portion of the minerals with which they come in contact. When these minerals are partly powdered, as in the soil, the effects of the plants' roots are, of course, greatly increased with the increased amount of surface exposed. Though the matter, thus removed, may seem very small in the case of any one plant, yet if we consider the effect of the whole mass of plant growth which covers the earth, we see that living plants are a force of great importance in the conversion of rocks into soil.

112. Action of Decaying Vegetable Matter.—The action of plants on the rocks does not cease with their life. When a plant dies, the process of decay begins, and, if freely exposed to the air for a sufficient time, nothing will be left but the ash or mineral matter which it contains. But it is very rarely that plant decay takes place in this manner. The dead remains generally gather under the growing plants in a slowly increasing layer, and thus, shut off from a free supply of air, the decay goes on very slowly, until this mass of vegetable matter becomes a black or brown compound, called *humus*. The *mold* under forest trees, and *swamp muck*, or *peat*, are good examples of humus; but it exists in nearly every soil. This humus assists in the destruction of rocks, and the production of soil, for the following reasons:

1st. Because, in its decaying state, it is constantly absorbing moisture, and keeping all bodies around it damp.

2d. Its slow decay is constantly producing carbonic acid, which is absorbed by the water of the soil, and thus acts powerfully upon the rock fragments below.

3d. Certain organic acids are also produced in decay, which act upon the rocks even more rapidly than does carbonic acid.

4th. Finally, with the complete decay of this humus, the mineral matter, which existed in the plants which formed it, is itself added to the earth from which it was taken.

113.—All these forces, which we have now studied, have together converted the sterile rocks of the earth's crust into fruitful soil; and when we consider that they have been at work for almost countless ages through the various periods of the earth's history, we see that they are abundantly sufficient to account for the layer of soil,

which nearly every-where covers the earth's rock strata. Nor is the process of soil forming yet completed. All of these forces are now in operation in different states of activity, and fertile soil is continually forming all around us, thus maintaining the earth's producing power.

SECTION II.

CLASSIFICATION OF SOILS.

114. **The Soil**, as already defined, is a mixture of minute fragments of a great variety of minerals. If we examine the soils of any section of country, we find them in what appears to be an almost infinite variety; in one locality, coarse gravel soils, in another, drifting sands or heavy compact clays, or, in still another, rich, dark-colored *bottom lands*, of great fertility and producing power. But, endless as this variety of soils appears to be, we shall still find that, by careful examination, we can divide them all into separate classes, which, though not absolutely distinct from each other, will help us much in our study. We may classify soils in four different ways: 1st. By their formation; 2d. By their composition; 3d. By their physical properties; 4th. By their position.

I. BY THEIR FORMATION.

Soils may be grouped into two classes: 1st. Sedentary soils; 2d. Transported soils.

115. **Sedentary Soils** are soils which have been formed where they are found, and have not been moved

since they were made. They are, of course, quite limited in their surface, and are only found in small patches. Fair examples of them are found upon the high limestone bluffs of Kansas, where the soft limestone rock has crumbled upon its surface, thus forming a layer of lime soil. Sedentary soils are generally very shallow. They are of no great importance, but are quite interesting because we know that they must have the same composition as the rock which they overlie; and that, by an analysis of the rock, we can obtain a very good idea of the general nature and value of the soil itself.

116. **Transported Soils** are those which have been carried or transported to a considerable distance from the rock layers from which they were formed. They are of three kinds, *drift*, *alluvial*, and *colluvial* soils.

117. **Drift Soils.**—These have been formed by the action of glaciers, and were brought down during the glacial epoch. Glacial drift, as we have already learned, consists of a confused mixture of fine earth, pebbles, and bowlders, the last sometimes many tons in weight. The particles are all much worn and rounded by the action of the ice. Drift soils cover a good portion of the northern United States; and the rocks from which they were derived may be found *in place* at a greater or less distance north of them. They are among our most valuable and fertile soils, as they contain the fine fragments and dust from a great variety of rocks. A country covered with drift soil may generally be known by the number of small round bowlders, called *hard-heads*, which are found through the soil; the surface of the country, also, is frequently quite irregular, being sometimes covered with great ridges or banks composed of sand, gravel, and bowlders, which are commonly called *hog's backs*, and are

believed to be remains of glacial moraines. Drift soils are even now being formed upon a small scale by the glaciers of the Alps and of Greenland.

When, as was usually the case, the drift, on being dropped by the melting ice, was still further transported by the streams which flowed from the glaciers, the different portions which composed it are found in different positions. To the north are found the large fragments and bowlders, near the place where they were first dropped by the melting glacier. Further south, will be found in their order the gravel, sand, and fine earth, the finest particles being carried farthest. Large tracts of sand, found in various parts of this country, are known to have been formed from drift.

118. **Alluvial Soils** are those which have been formed by the action of running water, generally over the valleys, or *bottoms*, of streams. These soils, also, are composed of fine, rounded particles, often soft and velvety to the touch, and, as we might expect, are sometimes found more or less stratified. The finer the particles, the longer they would be held by running water, and the farther they would be carried. Hence, when we examine a deposit of alluvial soil, we find the coarse stones and bowlders lowest and nearest the source of the stream; the finer gravel and sand, next above and still farther down the stream; and, lastly, the fine earth and silt, which would only be dropped by the water when it began to run slowly and evenly. Alluvial soils, such as are found over the valleys, or *bottom lands*, of our large rivers, are among the most productive soils known. Sometimes drift soil is worked over by streams, and converted into alluvial formations. A genuine alluvial soil can be known from the fact, that it generally contains rounded pebbles of

soft rock, which could not exist in drift soils made by glaciers.

119. **Colluvial Soils.**—These may consist of either drift or alluvial matter; but they always contain a quantity of sharp, *angular* rock fragments, showing either that they have not been transported far, or else, that they are a mixture of sedentary soils with drift or alluvium.

II. BY THEIR COMPOSITION.

The great mass of soils may, from their composition, be divided into seven general classes, which, from a scientific point of view, are neither distinct nor clearly defined; but which answer the purpose of a practical classification. By this classification, then, we have *gravelly*, *sandy*, *clayey*, *loamy*, and *calcareous* soils, *marl*, and *peat*.

120. **Gravelly Soils** are those containing an abundance of small stones or gravel. The value of a gravelly soil depends not only on the general size or coarseness of the pebbles, but also upon the nature of the mineral which composes them. A pure, coarse, quartz gravel would be almost utterly barren and useless. But when the gravel pebbles contain other valuable minerals, such as feldspar or limestone, we may have produced a soil of great fertility. Nearly every gravelly soil contains much fine, earthy material, generally of the same nature as the coarse pebbles. This finer soil sustains and nourishes the crop, while the coarse gravel drains the soil and acts as a storer and regulator of the sun's heat. For this reason, many gravelly soils are among the richest and *quickest* of all soils. They are, however, apt to be *leachy;* that is, to have the plant food washed out of them by water.

121. **Sandy Soils.**—A soil, to be called sandy, must consist of at least ninety per cent of sand. By the word *sand*, we may mean: "Small, granular fragments of rocks, no matter of what kind." Hence, in this class may be included soils of every grade of value, from the most productive to the most utterly worthless; but we commonly mean by sand, fine grains of *quartz*, beds of which, if pure, are almost absolutely barren. Sandy soils, however, always contain fine fragments of other minerals, so that many of them rank very high for their fertility. The famous "green sands" of New Jersey contain so much of the mineral, called *glauconite*, that they are largely used upon other soils as a fertilizer.

122. **Clayey Soils** are those consisting mostly of fine, adhesive matter, generally *clay*. These soils are heavy and sticky when wet; are not easily penetrated by water, and when dried by the sun, bake and crack. Pure clays are for this reason *cold*, and, generally, poor soils; but, when mixed with other materials, they are exceedingly strong and durable. Their various colors—yellow, red, brown, etc.—are owing to the oxide of iron which they contain. Many soils are called clayey, which contain no genuine clay at all. They are so called because they have the same general heaviness and appearance as clay, though they consist of other fine matters.

123. **Loamy Soils** embrace all grades of soil between clay and sand. They consist of mixtures of both, in various proportions. Loamy soils have neither the great heaviness or sticky qualities of clay, nor the loose, drifting character of sand. They are named *heavy clay loams*, *sandy loams*, *light sandy loams*, etc., according to the quantities of sand and clay present. Loams make the greater portion of our more valuable farming lands.

124. **Calcareous or Lime Soils** are those, of which carbonate of lime forms a large proportion. They are known from the fact that, when any acid, such as vinegar, is poured over them, they bubble violently from the escape of carbonic acid. Many Kansas soils contain enough lime to be properly called calcareous soils. When mixed with other materials, these soils are called *calcareous sands*, *clays*, or *loams*, according to the nature of the material.

125. **Marls** are mixtures, in about equal parts, of finely divided clay and carbonate of lime. *Shell marl* is nearly pure carbonate of lime, often found at the bottom of swamps.

126. **Peat** is partially decayed vegetable matter, produced by the slow decay of plants and their remains under water. *Peaty soils* are those containing much of this half-decayed vegetable matter. Soils produced by the decay of plant-remains *not* under water, are called *vegetable molds*. The mold under forest trees, formed of fallen leaves, twigs, etc., is the best illustration of this class.

III. BY THEIR PHYSICAL PROPERTIES.

127. Again, soils may be divided into *heavy* and *light* soils; but, as these words are not here used in their ordinary sense, this division requires some explanation. By *heavy* soils are meant, not those which have great weight, but those which are so compact in their structure that they strongly resist the movement of the plow through them, and hence are hard and heavy to cultivate. And, on the other hand, by *light* soils are meant those which are so light and porous in their texture that they can be lightly and easily cultivated.

128. **Absolute Weight of Soils.** — Soils vary much in their absolute weight, and many which in this sense may be heavy are really *light soils* to the farmer; and, on the other hand, many soils which are light in their actual weight are *heavy soils* to the farmer. For example, dry sand weighs 110 pounds to the cubic foot; ordinary soil, 90 pounds; heavy clay, 75 pounds; and peat soils, from 30 to 50 pounds to the cubic foot. Sandy soils, however, as we all know, are in the farmer's sense of the word the lightest of all soils, because they are easiest to work, while in actual weight they are the heaviest soils known. Clay, also, which we call a *heavy soil*, because hard and unyielding to the plow, is really a light soil in actual weight. Peat soils are light in both senses of the word, having little actual weight, and being loose and porous.

129. **Specific Gravity of Soils.** — By this we mean their *relative* weight as compared with an equal bulk of water. The specific gravity of all soils is nearly the same. A cubic foot of water weighs 62½ pounds. Upon comparing with this a solid cubic foot each of a great variety of soils, from which all the air had been driven, we would find their average weight to be 165.62 + pounds, and hence their average relative weight or specific gravity is 2.65. In this experiment we must, of course, weigh simply the *solid* soil. If we should take the soil in its ordinary porous condition, containing much air, we should of course get a much smaller number, which would not be its true specific gravity. The mechanical condition of the soil has much to do with its fertility. Up to a certain point, the more finely divided, the greater will be its fertility, because every part can be easily penetrated by the plant's roots. But this fine condition can be carried too far, and the soil may become so finely divided that, when

wet, its particles will stick together in a hard, compact mass, which can not be penetrated by the growing roots. It then becomes, in the farmer's sense, a heavy soil.

IV. BY THEIR POSITION.

Under this head soils are commonly divided into three classes — *surface soil*, *subsoil*, and *hard-pan*.

130. **Surface Soil.** — By the surface soil is meant that portion ordinarily stirred by the plow, and penetrated by the rain and the roots of the growing crops. It is generally of a dark color, because it contains more or less organic matter from decaying rootlets, etc. This layer is sometimes called the *active soil* or *tilth*.

131. **Sub Soil.** — By the subsoil is meant that soil layer immediately beneath the surface or active soil. It is generally more compact, less stirred in cultivation, and sometimes of a different color. But in long cultivated soils, the surface soil shades so gradually into the subsoil that it is sometimes impossible to draw a line telling where one begins and the other leaves off. In other cases, the division between the two can be clearly traced by the eye.

132. **Hard-Pan.** — This is the hard, compact layer, wholly beneath the subsoil. In the condition of hard-pan, the soil is really returning again to the condition of rock — the fine particles of soil, packed into a compact mass, are being slowly cemented together by the solutions of mineral matters brought down by the water of the soil, so that, if undisturbed, the hard-pan will become solid rock. When this layer is at the bottom of a swamp or marsh, it is called *moor-bed pan*.

SECTION III.

THE FARM SOILS OF KANSAS.

133. **The general surface** of Kansas is a rolling prairie; but it is an undoubted fact that the prairie surface is slowly decreasing, while the timbered areas are slowly increasing in extent. This is owing, both to the planting of trees by settlers and to the constant decrease of prairie fires. The farm-soils of Kansas, while in many respects similar to those of the surrounding states, yet present some distinct and peculiar features. The soil of this region was probably, in part at least, of drift origin, but this has since been very greatly changed in its character by the action of water, so that little of its true drift-nature remains. As we have already learned, the bowlders or hard-heads of the glacial drift are only found in comparatively small numbers, scattered over the north-eastern portions of the State.

134. **Bluff-Soil.**—The soil of the Bluff formation occupies the eastern portion of the State, along the Missouri river, and is very marked and peculiar in its nature. It has been formed later than the drift, is frequently of great depth, and through its entire mass is composed of fine earthy matter, with little or no gravel or stones. It is probably the accumulated sediment of the river, formed immediately

at the close of the glacial epoch, before the present channel was cut. Soil of the same kind is found in exactly similar position in Iowa, Nebraska, and Missouri. But the great mass of the soils of the State may be divided into three general classes — *low bottom*, *second bottom*, and *high prairie*.

135. **Low Bottom.** — In this class are included the exceedingly rich alluvial soils occupying the low, flat valley beds of our rivers, but a few feet above water level. They have been formed from the accumulated material brought down by the rivers in flood seasons, and dropped by the gradually subsiding waters. They are soils of great depth — frequently over 25 feet by actual measurement — and probably constitute the most valuable farming lands of the State. The soil is a rich, dark loam, sometimes almost black from the great abundance of organic matter. This soil has great capacity for resisting the injurious effects of drought.

136. **Second Bottom.** — The soils of this class include the large areas of farming lands extending along the next terrace above the low bottoms. They were formed in the same manner as the latter, but at an earlier period, when the rivers covered a much broader and deeper bed than at present. The second bottom soils probably make up the greater part of the first-class farming lands of our State; they are scarcely less inferior to the preceding class in fertility, though a trifle less rich in organic matter.

137. **High Prairie.** — This class includes the high rolling uplands of the State, covering much of its central and western portions. The soils of Kansas are largely of this class, and are probably in great part of local origin. They have their origin in the reduction of the rocks of carboniferous and cretaceous formations of the State. The

undulation of the strata of these formations in Kansas is such that their edges have been exposed to the weathering action of the atmosphere, frost, water, etc.; by this means they have become crumbled, and their fine material has been intermixed, and strewn over the uplands and slopes, where we find it compacted into soils, sometimes of great depth. Generally it will be found, in any locality, that the upland soil has, as the basis of its composition, the same materials as the rock strata of the neighborhood.

The comparison of these local soils with the rock strata from which they have been derived, will always be found a very interesting study.

A good illustration of this connection is shown in the vicinity of St. George, in Pottawatomie County, where there exists quite an extensive tract of sandy soil. This must plainly be referred to the extensive deposits of Upper Coal Measure sandstone and sandy shales, known to be the immediately underlying rocks of this locality; for as we ascend to the higher grounds, with their overlying limestone, clay, and marly deposits, we are at once impressed by the marked change in the character of the surface soil. Similar striking illustrations of the derivation of local soils from the immediately underlying rock strata are shown at many points on the slopes bordering the valley of the Kansas River, as well as in other portions of the State.

138. **Special characteristics of Kansas Soils.**— The soils of Kansas, in general, are well known as among the most fertile and productive in the United States; and are specially remarkable for two reasons: 1st. Their power of resisting the ruinous effects of excessive drought. 2d. Their great fertility under continued and exhaustive cropping, without the use of fertilizers. The first characteristic is every-where noticed by the most careless observer. Not

only does the capacity of the soil for moisture seem almost infinite, but its retaining power is equally great. This valuable property is probably owing to the large amount of organic matter present in all our soils, giving them their rich, dark character. Frequently, after a heavy shower, the soil will be found moist only to the depth of an inch or two; and only after prolonged storms will it be found sensibly wet to any great depth. These soils *dry* quite as slowly as they become wet; and, after weeks of dry weather, the surface, when brushed away for an inch in depth, will be found underlain by dark, damp earth. Hence, the long periods of excessively dry weather which occur in many growing seasons, and which would otherwise prove very disastrous, are here met by the large stores of moisture, slowly carried up to the rootlets of the growing crops, which are thus kept fresh and luxuriant.

The second characteristic of Kansas soils is equally a matter of common observation. Perhaps in no region have heavy and exhausting crops been grown continuously with so little care, either in cultivation or in the use of fertilizers; and yet in very few localities is the fertility of the soil sensibly reduced. Careful culture and the use of fertilizers is almost invariably followed by as heavy crops as are known ever to have been grown.

NOTE. — A chemical analysis of the soil, while it proves nothing of itself, is frequently very interesting. The analyses which have been made of numerous Kansas soils, by the writer, show, among many other interesting things, the presence of a great quantity of organic matter, which, in rich soils from the center of the State, frequently amounts to over ten per cent of the entire weight of the soil.

SECTION IV.

RELATION OF SOILS TO CROPS.

139. There is probably no subject in connection with the origin and formation of soils which is less understood, or concerning which there are more false impressions, than that of the *relations* which exist between soils and the crops to be grown upon them. We shall study only the more important of these relations here.

140. **Fertility of Soils.** — By a fertile soil we commonly mean one which, in an average season and with ordinary cultivation, will produce an average standard crop, such as wheat, corn, rye, etc.; but it is plain that this fertility of the soil is only relative, and depends upon many other circumstances than the simple presence of the elements of plant food in the soil.

141. **Influence of Climate.**— Climate, above all other circumstances, determines a soils fertility. There are very few soils which are barren or unproductive from the mere absence of the elements of plant food; but there are large tracts upon the earth's surface which are no better than deserts, not because the soil is sterile, but because the conditions of climate — such as lack of rain, excessive cold in winter, or heat in summer — are unfavorable to the growth of vegetation. In like manner, a soil which in a favorable

season is very fertile and produces an abundant crop, may, in a season of drought, prove utterly barren and unproductive. On the other hand, a soil which is naturally light and poor, may, in an unusually favorable season, yield a thrifty crop.

There are other physical circumstances, also -- such as standing water, poor natural drainage, etc. — frequently existing in compact heavy soils which may render a tract of land naturally fertile almost useless for cultivation.

142. **Special Crops.** — Among farmers, fruit-growers, and practical men generally, there is a very wide belief that for each particular crop there is also a particular kind of soil best adapted to its growth and cultivation. There are many facts in our general experience which would seem to support such a theory. For example, we all know that wheat generally does best on a high, open, lime soil; among fruits, pears are safest on a heavy clay soil; grapes, upon an open gravel or a loamy soil; while certain other crops prove most productive on warm, sandy soils. The explanation of all this is probably to be found not so much in the different composition of these various soils, as in their different *physical* peculiarities, such as warmth, moisture, drainage, etc., which seem to particularly adapt them to the crops in question. Out of this general experience above mentioned, there has grown another popular theory, which contains little truth, and has but few facts to sustain it, viz., that by analyzing a soil — that is, finding out the elements which compose it — it is possible to tell what particular kind of crop it is best adapted to produce.

This theory, which is now generally regarded by scientific men as untrue, has grown out of simple theorizing, in a manner which we may briefly explain as follows: If we burn a plant, we have left a dry powder which we call

its *ash;* this ash represents that portion of the plant's food which it has taken from the soil, and is absolutely necessary to its growth. Now it has been argued that if we could find out, by analysis, the elements which compose this ash of the plant, we should at once know what elements the soil must contain to grow it; and that, if these proved to be wanting in the soil, we could add them in their proper proportions as fertilizers. This theory, when put in practice, is found to fail utterly, because it takes no account of another element of the plant's food, called the *nitrogenous* element, because it furnishes nitrogen to the plant. This is fully as important as the plant's ash-food, and without it no crops could be grown. It is impossible for us to tell from the analysis of a soil what crops will be specially adapted to it, as it is probable that, with very few exceptions, all *fertile soils* contain, in greater or less quantity, the mineral elements necessary for the growth of all standard crops. Whether these can be grown upon them profitably or not will depend upon their physical condition, the nature of climate, method of culture, etc.

143. **Chemical Analysis of the Soil.** — From the last paragraph we conclude that, although by a *chemical* analysis of a soil we are able to find the exact number and proportion of all its elements, yet this will not of itself tell us any thing as to its fertility, or the crops which it will best grow. The reason of this is plain, when we know the condition in which the minerals composing the soil exist. The mineral elements of the soil are of three kinds:

1*st.* The mechanical basis of the soil, which simply serves to hold the plant, and which gives little or nothing to its growth. For example, *sand.*

2*d.* The minute mineral particles, which, under the weath-

ering action of the air and water, are rapidly being powdered and becoming plant-food.

3d. The immediately soluble and available mineral food of the plant, which is ready to be at once dissolved and taken up by the plant's roots.

The present fertility or barrenness of a soil must of course depend upon the amount of the *third* class present; but it is not possible for chemical analysis to tell us accurately what part of the mineral elements of the soil is in a condition to be at once useful to the plant, and what is of no value, or only very slowly becoming plant food. The only possible way for us to know absolutely a soil's producing power is to measure the crop which it will grow. Still, a chemical analysis of the soil is always interesting, and there are cases in which it may prove valuable. Whenever a soil is found to be barren, from the entire want of any part of the plant's food, or from the presence of any poisonous compound, a chemical analysis will always point out to us the cause of the trouble, and the remedy.

144. **Mechanical Analysis of the Soil.**—For practical uses a *mechanical* analysis of the soil will give us a very good idea of its general condition. This can easily be performed as follows: A portion of the soil may be weighed and passed through a moderately coarse sieve; that which can not be passed through may then be weighed separately, and called *gravel* and *coarse sand.* The part which passes through the sieve should be placed in a vessel of water, stirred rapidly, and allowed to settle for a few moments. That which settles to the bottom may be dried, weighed, and called *fine earth.* In the water above the fine earth will be found a quantity of exceedingly fine matter, held suspended by the water. To separate this,

the water may be passed through a filter-cone, made of white, unsized paper, and the matter which collects upon it may be dried, weighed, and called *impalpable matter.*

The value of such an analysis depends upon the fact that, other things being equal, the finer the particles of a soil are divided, the greater will be its fertility. In several soils, of nearly the same composition, the one having the greatest quantity of fine matter will carry the heaviest crops.

Regions which have long been celebrated for their enormous crops, will almost invariably be found to be those having a very finely divided soil. This would be very naturally the case, because a finely divided soil offers a much greater surface to the weathering action of the air and water, so that more plant food becomes soluble; and, at the same time, the little rootlets of the plants themselves can spread far more freely and absorb this extra supply of plant food. Of course it is possible, as in a heavy clay soil, to have this division of the soil particles carried so far that all these good results will be lost, and a solid, compact *water-tight* soil may be the consequence.

145. **Preparation of Soils for Crops.** — The ordinary practices of the farmer in preparing his fields for crops, although followed for centuries simply because they have been found to give us the best results, can yet all be explained upon scientific principles. Such simple operations as plowing and harrowing have for their first great object the pulverization of the soil. By these means we obtain:

1*st.* A free movement of the little rootlets of the young plant through the soil.

2*d.* A clear passage for the water of the soil, so that after rains it will be rapidly absorbed, and, during dry weather, easily carried up to the plant from the damp earth below.

3d. The free presence of air in the soil, absolutely necessary to the growth of the plant.

4th. An abundant supply of mineral food, which is furnished the plant by the process of weathering, constantly going on in an open soil.

The process of cultivation, during the growing season, carries on all these operations still more perfectly. By fall plowing we call to our aid the powerful action of frost, during the winter, upon the hard minerals of the soil. This action of frost is so strong, that, during a single winter, it will produce, upon an exposed soil, fully one third the effects of plowing.

146. **Fallowing.**—The operation of fallowing is generally made upon old or worn out soils, and is simply the process of weathering upon a large scale; that is, the soil is plowed and exposed, in a naked condition, to the action of air, water, frost, etc., for one or more seasons. By this means the soluble parts of the plant's food, which had become exhausted, are again restored by the weathering of other mineral particles, and the soil is then ready for another crop.

147.—From what we have already learned of the influence of climate, and the physical conditions of a soil, upon its fertility, it is evident that no fixed rule as to the method of preparing the soil, for any particular crop, can be laid down as suitable to all localities. Many methods which are employed, with great success, in the Eastern States, fail entirely when used in the growth of Kansas crops. In every case the nature of the soil and of the crop, the general character of the climate, and the peculiarities of the season, must all be taken into consideration in determining the method which can be followed with the best hope of success.

SECTION V.

EXHAUSTION OF SOILS.

148. — The question of the exhaustion of soils has always produced much dispute and discussion, and, even at the present day, there can hardly be said to be any uniform opinion upon the subject. By some it is maintained that the exhaustion of our soils is a danger against which farmers must constantly guard themselves; while others believe that such a danger is wholly imaginary, and never occurs in actual practice. There are certain facts, however, which can not be questioned, and which have been observed by every cultivator.

149. **Worn-out Soils.** — It is well known that when any heavy crop is grown, for years in succession, upon a piece of land, without the use of fertilizers, the yield will each year become less and less, until finally it will be so small as hardly to return to the farmer the seed itself. Such an experience is not uncommon where corn and wheat are grown for a long period of years without fertilizers. Other crops, which are more exhausting in their effects upon the soil, produce these results more completely even than the grain crops. The tobacco plant is one of the most notable in this respect; and the worn-out tobacco fields in portions of the Southern States, especially in Vir-

ginia, are well-known examples of its effects after long continued cropping, upon the same soil.

If we would seek an explanation of these effects, it is plain that we must look for them in the plant-food taken from the soil. This we know to be of two kinds: first, the mineral food, or what we call the plant's *ash;* second, its *nitrogenous* food, furnished largely by the decaying organic matter of the soil. Of these two classes of plant food, the latter is, probably, the more rapidly exhausted by the continuous growth of the same crop, but the plant's mineral food is also exhausted by it.

These facts are well shown in an estimate made by Professor Johnson, upon the hay crop, as follows: A hay crop probably carries off more mineral matter than any other known; thus, one crop of hay, of two and a half tons, will remove 400 pounds of mineral matter from each acre of the soil. When we compare this with the whole weight of the soil, about 4,000,000 pounds to the acre, to the depth of twelve inches, the quantity seems very small. But when we remember, that out of *one hundred* parts of this soil, not more than *one* part gives food directly to the plant, we see that the number of hay crops which a soil can produce is by no means unlimited. The same might be shown of the other staple crops of the farm. We can, therefore, readily understand, how, by continued cropping for long periods of years, without the return of any equivalent in the form of fertilizers, we may easily reduce the producing power of our farms to a very low point.

150. **Theoretical Exhaustion.**—Taking these well-known facts as a basis, many writers have attempted to prove, that a system of farming which does not return to the soil, in the form of fertilizers, whatever is taken from it in the form of crops, would finally produce such an

exhaustion of the soil that it would sustain no plant growth whatever. But such absolute exhaustion is impossible, and, as Professor Johnson says, "exists only in the imagination." A soil, once fertile, could never be reduced to utter barrenness simply by cropping.

151. **Practical Exhaustion.** — While complete exhaustion of the soil, so that it will sustain no plant-life, is impossible, yet it is very easy to bring about a *practical* exhaustion, by careless culture. This is the case, to use the language of Prof. Johnson, "when the cost of cropping is greater than the value of the crop grown." Hence, no soil can be called productive which does not produce a crop whose value is more than sufficient to cover the time, labor, and money consumed in raising it. Whenever the value of the crop is too small to cover this expense, the soil is practically exhausted, and further cultivation of it is unprofitable.

From this it will be seen that there are many other elements, which are very important in the exhaustion of soils, besides the simple quantity of the crop produced: such are, the market value of the crop, distance from the market, cost of transportation, etc. Let us suppose, for example, that we have two equally fertile fields, one in Kansas, and the other near New York City. Without taking into consideration the value of the land, it is plain that, with exactly the same system of cropping, the Kansas field would become practically exhausted first, because the *value* of the crop is much less in Kansas than in New York, and the cost of transporting it to its final market much greater.

When a soil has become practically exhausted, it is very easy to restore it again, to its first fertility, by proper treatment. It has become exhausted because its *present* available plant-food has been nearly consumed. The proper

plant-food may be restored either by the use of fertilizers, or by letting it lie *fallow* for a number of seasons, so that its reserve matter may be made available in this capacity by the weathering action of the atmosphere.

152. **First-class Farming.** — No process of farm-culture can be regarded as first class which does not aim to accomplish these two things:

1*st.* To so change or rotate the staple farm crops that no field shall become exhausted, to any extent, of any one kind of plant-food.

2*d.* To preserve the fertility of the soil at a fixed high standard by returning to the soil, as far as possible, a full equivalent for every crop which has been taken from its surface.

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